CENTRAL DELICIAS, CUBA.

A HANDBOOK

CANE-SUGAR MANUFACTURERS

CHEMISTS.

BY

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SIXTH EDITION, ENLARGED.

SECOND IMPRESSION, CORRECTED.

TOTAL ISSUE, TEN THOUSAND

Wahr
6741
Eng. Chem,
11 28-1922
Eng-(For chem.)

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DEDICATED
IN
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TO
M. CH. GALLOIS
AND
M. FRANÇOIS DUPONT
PAST PRESIDENTS
OF THE
ASSOCIATION DES CHIMISTES DE FRANCE
BY THE AUTHOR

PREFACE TO THE SIXTH EDITION.

THIS edition is enlarged to include a chapter on Evaporation and Juice Heating, by Prof. W. H. P. Creighton, Dean of the Department of Technology, The Tulane University, New Orleans, La. Prof. Creighton's long experience as an officer in the United States Navy, and in teaching in the engineering departments of Purdue and Tulane Universities, has eminently fitted him for the preparation of this article. I extend my thanks to him.

A few typographical errors have been corrected and some slight changes have been made to bring out certain process descriptions more clearly.

G. L. SPENCER.

CAMBRIDGE, MASS., 1917.

PREFACE TO THE FIFTH EDITION.

THE section devoted to the manufacture has been greatly enlarged in this edition. The processes in use in the manufacture of raw, plantation white and refined sugar are described.

Through the courtesy of Mr. George P. Meade, Superintendent of the Cardenas (Cuba) Refinery, I include a chapter on sugar refining and refinery control as is practised in the United States.

The book has been largely rewritten. The chemical section has been revised to meet the conditions of the very large factories now in operation. Additional tables are included and several of the older ones have been replaced by recent tables.

G. L. SPENCER.

WASHINGTON, D. C., 1915.

PREFACE TO THE FOURTH EDITION.

THE first edition of this book was written at a time when few cane-sugar factories employed chemists and but little had been written, in English, concerning this branch. of sugar-work. Many chemists are now engaged in the cane-sugar industry with the result that much more material is available in the preparation of this book.

The proper control of a sugar-factory by the chemist requires a knowledge of the methods of manufacture, in addition to a chemical training. For this reason a brief description of manufacturing processes is included in this edition.

With the large increase in the scale of manufacture during the past few years, the greater complexity of processes, and the tendency toward the production of one grade of sugar, whether raw or refined, the necessity of having a competent chemist in the factory is becoming generally recognized.

<div align="right">G. L. SPENCER.</div>

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MANUFACTURE OF CANE-SUGAR.

RAW MATERIAL.

1. Sugar-cane.—Cane is a large grass, belonging to the genus *Saccharum*. The mode of its growth varies with variety, climate, soil and cultural conditions. Until within comparatively recent years its flowers were believed to be sterile. The plant "arrows" or blossoms usually only in the Tropics and then not freely every year. A very few arrows have been noted in Louisiana in exceptionally mild years.

Large numbers of seedlings are now produced in experiment stations in various parts of the world in the search for new varieties. The seedlings are crossed with other seedlings and with existing varieties in order to develop certain characteristics. These experiments have resulted in several varieties which are now in broad culture. The new varieties are selected for some particular qualities such as richness in sucrose, resistance to disease, persistence of type, time of ripening, milling qualities, fuel value, color, etc. The most extensive use of seedling varieties is in Java. There few of the old varieties are now cultivated.

It is generally believed in Cuba that a year in which the cane arrows freely is not usually very productive. Such cane, however, is often very rich in sucrose and of low invert-sugar content. It increases in its sucrose content for several months after flowering, and, as is true with other canes, deteriorates as regards the sugar when the rainy season begins. The yield of cane, however, may be small, since the plant grows little taller and heavier after flowering.

Sugar-cane varies greatly in richness in different countries and even in the same country. It does not often exceed or even attain a sucrose content of 17 per cent in Cuba, but this is sometimes surpassed in other countries. A cane in Louisiana containing 12 per cent of sucrose is considered very rich.

Sugar-cane is propagated by means of the buds that are located at the nodes. Pieces or cuttings of the cane are planted with a very shallow covering of soil or in certain localities are only partly covered, but in this latter event are irrigated. Each bud produces a plant and from each of these there are several shoots or suckers. These form a clump or stool of canes. The cane under suitable soil and climatic conditions is usually planted but once in several years. New plants, termed "ratoons," spring up from the stubble, after harvesting the crop, and produce a second crop and so on. Fiscal or soil and climatic conditions sometimes limit the crop to "plant-cane" or to plant-cane and one or two ratoons.

Dark-colored varieties are usually produced in sub-tropical regions and the light-colored, greenish or yellow canes in the Tropics. The Tropics, however, will produce canes of any variety. The usual Cuban cane is the "cristalina" variety and is of a light color.

Normal sugar-canes are never hollow or partially so. They contain approximately from 87 to 90 per cent of juice and some water, in composition with certain plant constituents (colloid water), that contains little or no sugar. Canes that are abnormal on account of some climatic or other conditions are sometimes hollow, but the proportion of such cane is usually very small.

The plant matures with the approach of cool or dry weather. Harvesting usually begins long before the cane is considered to be ripe, in order to obtain a long working season. If the factory is in an irrigated district, the distribution of water is suspended a few weeks before the cane is to be harvested, to promote ripening. The sucrose content of the stalks increases and the reducing sugars decrease as the plant approaches maturity.

The stalks are cut off close to the ground in harvest-

ing and should be topped just above the highest colored joint. These conditions vary somewhat with the country and whether the fields are irrigated. Where irrigation is practised, the two or three top joints are usually removed for use in planting new fields. Since these joints are of lower sucrose and higher glucose (invert sugar) content than the rest of the stalk, the raw material entering the factory is improved by their removal. Owing to scarcity of labor in Cuba, the canes are often topped too high, thus giving the laborer a larger wage and the farmer more cane, but reducing the return to the manufacturer through a smaller yield of juice in milling and the necessity of grinding the poorer parts of the stalk. It is customary in harvesting in Java to dig the earth from about the plants and cut off the stalks a foot below the surface of the ground. The top joints of the canes are reserved for "seed" in planting. The tops, as stated, are only available for planting when irrigation of the fields is practised.

The sugar content of the cane deteriorates rapidly after the stalks are cut, therefore these should be conveyed to the mills as soon as possible and be immediately ground. The small factory usually has an advantage with respect to the freshness of its raw material, owing to its proximity to the fields as compared with the large factory. The latter must have a considerable quantity of cane cut in advance of grinding, which must lie exposed to the sun in the fields, otherwise regularity in the delivery of the raw material cannot be assured.

The writer has noted a fall of several degrees in the coefficient of purity of the juice from canes that had been cut and left lying three or four days in a hot climate, exposed to the sun in cars and on the ground. He has also stored cane under cover, during cool weather in Louisiana, with no appreciable deterioration in a period of more than two weeks.

The lower leaves of the cane become quite dry as the harvest season advances. These often take fire through accident or intention. It is usual to burn cane fields that contain irritating weeds or when the cane is small and trashy. This burning is to facilitate harvesting and it is practised especially where labor is expensive. The cane is not injured

by burning, but it must be harvested very promptly to avoid loss through deterioration, which is accelerated by the burning. The rate of deterioration is greatly increased should rain fall upon the burned cane. The manufacturer agrees in most Cuban cane contracts to receive burned cane up to and including five days without deduction from the price, but in the event of rainfall he may refuse it at any time. The purification of the juice is not usually so readily accomplished with burned as with sound cane, and the heating-surfaces of the evaporator foul sooner. The fine particles of carbon sometimes persist through the manufacture and finally appear in the sugar. It is preferable to grind a mixture of sound and burned cane rather than burned cane alone, since the mixed juices are more readily purified.

The method of transport of the cane to the factory varies with local conditions. Small factories usually transport their cane in carts or small cars. Portable railways are largely used in the Hawaiian Islands and in Java, but almost not at all in Cuba. The cane is brought to the factory or railway in Cuba in bullock carts. It is flumed to the factories in the Island of Hawaii and in British Guiana, usually transported in punts. The use of flumes and punts complicates the estimating of the percentage yield of juice the mills. Inferential methods, based upon the analy the cane and juice and the weight of the latter, may then become necessary.

Sugar-cane is usually sold to the factories without regard to its richness in sugar or the purity of its juice. It is difficult to devise an equitable method for the purchase of cane upon a basis of its analysis. (See page 382.)

The following table showing the composition of the stalks of Louisiana cane at the time of harvesting, November-December, is inserted through the courtesy of Dr. C. A. Browne, Chemist of the New York Sugar Trade Laboratory and formerly of the Louisiana Sugar Experiment Station. The figures are condensed from many analyses of the purple variety of the cane. The composition of the cane varies with climatic conditions, character of the soil, manner of fertilization and cultivation, the age of the cane and its variety:

COMPOSITION OF LOUISIANA SUGAR-CANE.

Water.................	74.50%		74.50%
Ash.................	0.50	Silica, SiO_2.................	0.25
		Potash, K_2O.................	0.12
		Soda, Na_2O.................	0.01
		Lime, CaO.................	0.02
		Magnesia, MgO.................	0.01
		Iron, Fe_2O_3.................	Trace
		Phosphoric acid, P_2O_5......	0.07
		Sulphuric acid, SO_3........	0.02
		Chlorine, Cl.................	Trace
Fiber.................	10.00	Cellulose.................	5.50
		Pentosans... Xylan......	2.00
		(Cane-gum) Araban.....	.50
		Lignin bodies, etc........	2.00
Sugars.................	14.00	Sucrose.................	12.50
		Dextrose.................	.90
		Levulose.................	.60
Nitrogenous bodies ...	0.40	Albuminoids.................	0.12
(Total N = .06%)		Amids (as asparagin)......	0.07
		Amido acids (as aspartic)..	0.20
		Nitric acid.................	0.01
		Ammonia.................	Trace
		Xanthin bodies...........	Trace
Fat and wax..........	0.20		0.20
Pectin (gums)........	0.20		0.20
Free acids...........	0.08	(Malic, succinic, etc.).....	0.08
Combined acids......	0.12	(" " ").....	0.12
Total..........	100.00%		100.00%

The juice of the cane contains nitrogenous substances
that are more or less objectionable in the manufacture.
Fritz Zerban [1] isolated asparagin, glutamin and tyrosin. A
part of the asparagin and a still greater part of the glutamin
are broken up in the manufacture with the result that aspar-
tic and glutamic acids accumulate in the molasses along with
undecomposed asparagin and glutamin. These amids are
largely responsible for the ammonia given off during the
evaporation of the juice. Acid amids and aminoacids are
positive molasses-makers.

A small amount of cane-gums (pentosans) and of fat and
wax find their way into the juice during milling; these to-
gether with the pectin acids and nitrogenous bodies make up
the organic solids, not sugar of the juice. The amount of
these organic impurities depends upon the age and variety of
the cane and also upon the pressure of the mill-rollers.
Their percentage is much higher in the juice from the second
and third mills than in the juice from the first mill;[2] their

[1] Eighth Int. Congress App. Chem. 8, 103.
[2] Cane-sugar, Prinsen-Geerligs, 2d edition, 31. Browne, La. Planter,
1904, 32, 49.

relative percentage is also higher in the juice from the diffusion-battery than in mill-juice. The fat and wax, the greater amount of albuminoids, and part of the gums of the juice are removed during the clarification.

The sucrose content of the cane and also the coefficient of purity of the juice vary greatly in different parts of the stalk. The juice of the nodes is of lower sucrose content and lower purity than that of the internodes. A similar difference exists between the lower and upper halves of the stalk.

Noël Deerr has analyzed whole canes, the pith, rind and node, and has referred the sucrose in each part to that in the whole cane on a percentage basis.[1] His figures are given in the following table for three varieties of Hawaiian canes. In using these figures it should be considered that the separation into pith, rind and node can be made approximately only:

Variety....	Rose Bamboo	Yellow Caledonia.	Lahaina	Lahaina	Yellow Caledonia.
Origin of sample..	Oahu	Oahu.	Oahu.	Maui.	Kauai.
Pith......	83	77.3	82.4	72.2	76.6
Rind......	4.7	8.7	6.9	8.8	10.3
Node.....	12.3	14	10.6	19	13.1

The cane contains coloring matters such as chlorophyll, anthocyanin and saccharetin [2] of Steuerwald. Chlorophyll is insoluble in water and is therefore readily removed in the purification of the juice. Anthocyanin is precipitated in the presence of excess of lime, hence is removed in the carbonation process. It is partially bleached by sulphurous acid. Anthocyan [3] is very soluble and decomposes rapidly. Saccharetin is present in the fiber of the cane. According to Steuerwald it turns yellow and is soluble in the presence of lime and other alkalis and is not altered in the carbonation and sulphitation processes. Saccharetin unites with iron to form an intensely black compound. Such saccharetin as is present in the raw juice passes through all the processes of

[1] Bul. 30, Haw. Sugar Planters' Exp't Sta., 36.
[2] Int. Sugar Journ., 14, 53.
[3] C. Müller, Bull. Assoc. des Chimistes de France, 31, 849.

manufacture and finally appears in the molasses. Saccharetin should be prevented from entering the manufacture by thoroughly straining the juice as it flows from the mills and by the non-use of alkaline imbibition water.

Sugar-cane usually contains three sugars,[1] sucrose, dextrose and levulose (d-Fructose, Fruit sugar). The dextrose and levulose are present in the very immature plant in nearly equal proportions, i.e., in the proportions in which these sugars are formed when sucrose is inverted by acids. As the cane matures the levulose content decreases and sometimes disappears. Levulose again always appears, however, in the molasses. This reappearance is due to isomeric changes in the dextrose when its solutions are heated in the presence of salts of the alkalis and alkaline earths, notably potassium salts. The reducing sugar content of Cuban cane-juice, levulose and dextrose, termed the "glucose" in the cane industry, usually ranges between 0.4 and 1.35 per cent. The reducing sugars are sometimes almost or quite absent from cane-juices. This condition existed for several weeks one season in the writer's experience at Magnolia Plantation, Louisiana.

The mineral or ash content of the cane-juice is quite variable. The range in the author's Cuban experience is between 0.25 and 0.6 per cent in the juice. The composition of the ash is also very variable. Potassium, figured as potash, K_2O, the most abundant constituent, ranges from about 25 to 45 per cent of the ash.

The composition of the ash of the juice also varies from year to year, as may be noted in the table on page 8, columns "A":

2. Manufacturing Season. — The season begins at greatly varying dates in various parts of the world. In the almost rainless districts where irrigation is practised, grinding may be prosecuted during nearly or quite the entire year. This is true in Peru and in parts of the Hawaiian Islands. The season of manufacture begins in October and November in Louisiana and lasts through December and often into Jan-

[1] Pellet reported raffinose in cane molasses, but its presence has not been confirmed by other chemists (Bull. Assoc. des Chimistes de France, 14, 139; see also Deut. Zuckerind., 22, 1439).

ANALYSES OF THE ASH OF CUBAN CANE JUICES

(Percentages of the Ash)

Factory and Crop Year ..	A (1913)	A (1912)	B (1912)	C (1912)	D (1912)	E (1912)
Silica, SiO$_2$.............	5.56	11.90	6.82	7.60	6.10	6.46
Iron and Alumina, Fe$_2$O$_3$, Al$_2$O$_3$................	19.00	12.48	4.80	8.20	5.44	3.00
Lime, CaO.............	7.62	10.25	10.77	13.02	5.77	4.70
Magnesia, MgO.........	6.55	6.83	7.88	7.54	5.17	5.01
Potash, K$_2$O............	25.15	27.14	32.64	29.30	43.66	46.28
Soda, Na$_2$O.............	5.35	2.32	3.20	4.00	1.88	1.36
Phosphoric Acid, P$_2$O$_5$....	5.44	7.15	Trace	3.90	4.79	4.21
Sulphuric Acid, SO$_3$......	15.02	9.84	10.75	17.94	12.15	4.08
Chlorine, Cl............	5.14	5.10	10.95	8.10	11.00	12.90
Carbonic Acid, CO$_2$......	2.68	9.59	7.47	3.02	8.22	10.53

uary. The season begins in December in Cuba and in Jan-
uary in Porto Rico. The usual manufacturing period of the
West Indies is from December until June, though grinding
may continue into September or even longer in parts of the
northeast coast of Cuba, with frequent interruption on ac-
count of rains in May and the following months. The Hawai-
ian season begins in November and continues about six
months, though climatic conditions in many parts of the
Islands permit a very much longer season. The factories
of the Dutch East Indies grind during the dry monsoon, or
from about May into November. This corresponds very
nearly with the Argentine season.

   The advent of the rainy season determines the close of
the manufacturing period in the Tropics. The rains not only
interfere with the transportation of the cane, but cause it to
renew its growth at the expense of its sucrose content.

EXTRACTION OF THE JUICE.

3. Milling Processes.—*Unloading the Cane.*—The cane is unloaded from the cars and carts by mechanical devices in the well-equipped modern factory. Many forms of such devices are in use, especially in Cuban factories.

Where the climate is cool and the cane deteriorates but little in storage, as in Louisiana, derricks are often used. These are usually arranged to lift the cane from the cars or carts and deposit it upon endless conveyors, termed carriers or elevators according to their form, or in large piles for the night work, or to prevent interruption in the cart or railway service. In the latter case, the same derricks are again used in picking up the cane and in placing it upon the carrier.

Raking devices are used in many Louisiana factories and to some extent in Java for pulling the cane from the cars or a platform onto the carrier.

Hoists and dumping devices are very generally employed in Cuba in unloading cars and carts. The hoists usually have a capacity to lift a half or a third of a car-load of cane at a time and drop it into the hopper from which it is carried to the mills by elevators. These elevators are heavy endless chains, fitted at intervals with arms which drag the cane with them. Chains or cables are passed under the load, in using a hoist, and are attached to a yoke, provided with a tripping device. The breakage of bundles often occasions loss of time in this method. However, the use of hoists greatly simplifies the arrangement of the railway tracks in factories using three milling plants.

Dumping devices are in great favor in Cuba. They discharge the cane quickly and with a minimum of labor. Further, there is little loss of cane in transit. There are two general types of dumping devices. In the one, the car is run upon a platform, which is then tilted and the load is discharged endwise through a swinging door into the hopper

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of an elevator. In the second type the platform is tilted side-wise. The stakes or sides of the car are hinged at the top and fastened at the bottom with latches, which are released when dumping the load. Hydraulic-power is usually em-ployed in tilting the platform. The platform is hinged at such points that the weight of the load itself causes it to tilt when the water is released from the hydraulic cylinders. With this arrangement very little water pressure is required to return the platform and car to a level position. It is probable that mechanical devices were first used for handling cane in the sorghum-sugar industry.

The cane should be promptly delivered to the mills. The
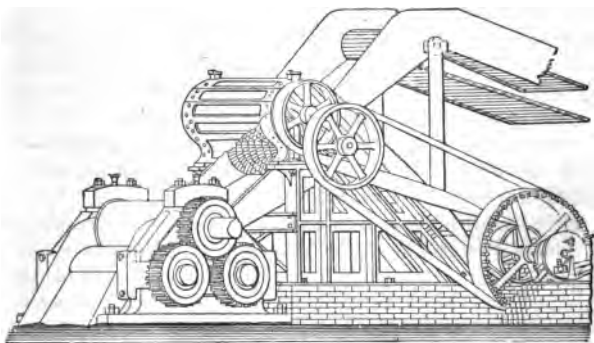
Fig. 1.

loss of sugar due to the exposure of the cut cane to the sun in the fields and cars is very large.

Milling Machinery.—Multiple-mills are used exclusively in crushing the cane and in expressing its juice. These usually consist of a crusher or shredder and three or more 3-roller mills. The crusher and shredder are designed to prepare the cane for milling by breaking down the hard structure and in the case of the crusher, extracting a part of the juice.

The first successful machine for preparing cane for milling was the National cane-shredder, Fig. 1, invented by Samuel Fiske and first used in Louisiana. This machine consists

essentially of two shafts carrying conical cutting disks which dovetail or mesh into one another. These shafts are rapidly revolved in opposite directions and at different rates of speed. The cane is torn into shreds by the disks. The little juice that is separated in the shredding process is immediately reabsorbed.
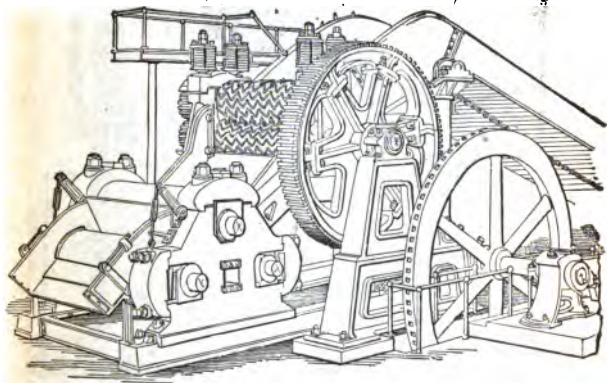
FIG. 2.

FIG. 3.

The Krajewski crusher, Fig. 2, was invented by Krajewski in Cuba after the introduction of the shredder into this island. A crusher-roll is shown in Fig. 3. The rolls are driven slowly by gearing and crush the cane, thoroughly breaking down the rind. A part of the juice is expressed and separated from the crushed cane and a part goes on with the latter.
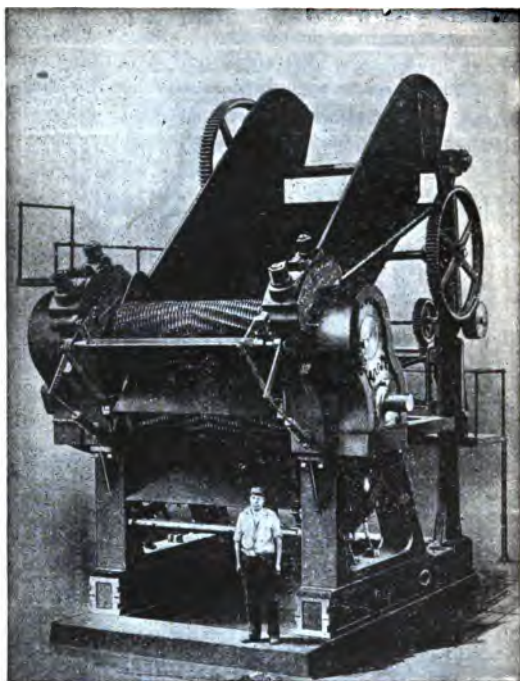
FIG. 4.
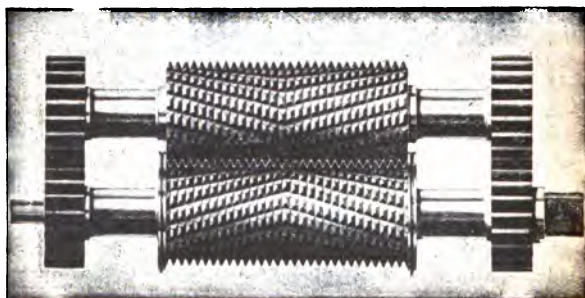
FIG. 5.

A second type of crusher is the Fulton, shown in Fig. 4. This differs in its cutting or crushing surface quite radically from that of the Krajewski crusher. The cutting teeth are V-shaped and are arranged spirally, 1.75 inches pitch, with the spirals working from opposite ends of the rolls, as is well shown in Fig. 5. There are also grooves separating the teeth into groups, and scrapers are provided to prevent clogging the teeth. This machine not only crushes the cane thoroughly, but also expresses a considerable part of the juice.

Farrel Foundry & Machine Co.
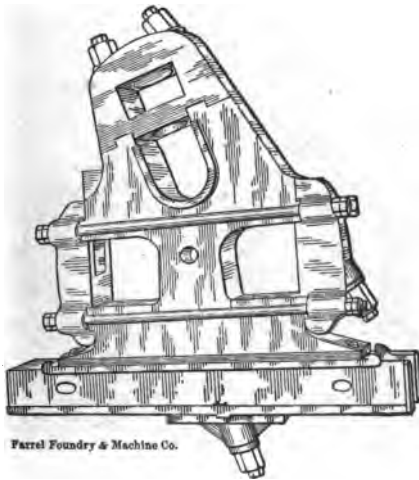
Fig. 6.

In some installations, especially in strengthening old milling plants, at moderate cost, a crusher is not used, but in its stead a special corrugated or blunt-tooth top roll in the first mill. Such rolls, especially a type known as "excelsior rolls," are very generally used in Java.

Present-day mills have always three rolls, as is shown in Fig. 1. The bottom roll, where the cane enters, is termed the "cane-roll," and that opposite the "bagasse" or "discharge-roll." The two bottom rolls are usually rigidly fixed in posi-

tion and the top roll is controlled by an hydraulic ram and
is so arranged that it may rise and fall or "float" with varia-
tions in the feed of the cane. Hydraulic pressure is applied
to the bagasse-roll by certain builders. A ram is shown in
in the top-roll cap in Fig. 7. The crushed cane, now called
"bagasse," is passed from one pair of rolls to the next by a
curved plate, variously termed a turnplate, knife, dumb-
turner, trash-turner, etc., according to the country in which
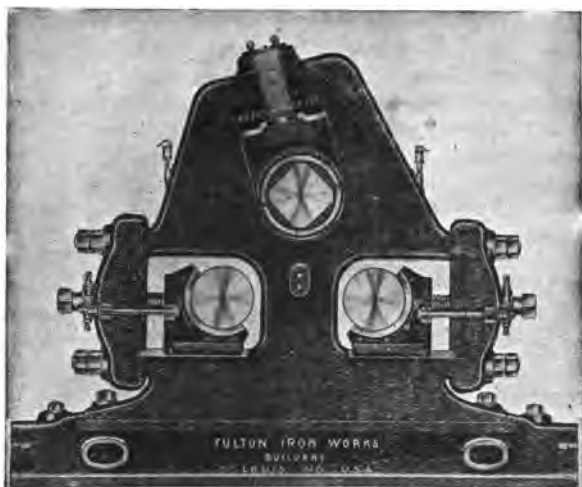
FIG. 7.

the mill is used. This is supported by a heavy steel turn-
plate-bar.

The mill-rolls are supported in massive castings termed
housings or mill-cheeks. The older types of housings are
shown in Figs. 1 and 2 and more recent models in Figs. 6
and 7. The crown wheels by which the bottom rolls are
driven from the top roll are shown in Fig. 1. The driving-
engine is connected through flexible couplings and gearing
with the top roll of the mill.

The Puunene housing, probably the original of the inclined

type, is shown in Fig. 6. A recent Fulton inclined housing is shown in Fig. 7. This latter dispenses with the king-bolts which one may note projecting above the top-roll caps of other types in Figs. 1, 2, and 6. The object in inclining the housing is to promote the "flotation" of the top roll. The cane enters the mill from the side toward which the housing is inclined. Since the greatest stress is between the bagasse and top rolls, by inclining the housing so that the resultant of this pressure and that between the cane and top rolls will follow the angle of inclination, the top-roll brasses will rise and fall freely in the housing or the roll will "float." With the usual types of housings there is a tendency for the bearing brasses to "bite" into one side of the slot. This biting-in results in friction that retards the free motion of the roll in accommodating itself to the work. The Honolulu Iron Works have overcome this tendency in their housings by fitting them with an hydraulic ram whose position may be so adjusted as to promote the free rise and fall of the roll.

Mill-rolls are cast of an iron mixture that will remain rough or acquire a "grain" with use that facilitates the feeding of the cane and bagasse. The rolls are often grooved to promote the feeding of the cane and the breaking down of its structure. These grooves are of various shapes, forming diamonds, zigzags, etc. Such grooves are little used except in Java. In the usual method, the rolls have peripheral V-shaped grooves, from three to six grooves per inch of roll length. The size of the grooves has been greatly increased in recent years, to reduce the slipping of the roll upon the bagasse. A return to small grooves and even comparatively smooth-bottom rolls is probable with the introduction of the deep juice-grooves described below.

The feed-roll in recent Hawaiian practice has juice-grooves $\frac{1}{4}$ inch wide by 1 inch to $1\frac{1}{4}$ inches deep, $2\frac{1}{4}$ inches pitch (P. Messchaert's patents). The depth of the grooves should be $1\frac{1}{4}$ inches in rolls 34 inches to 36 inches in diameter and less in smaller rolls. The method of grooving is illustrated in Fig. 8. Special scrapers are used to keep the grooves free of bagasse. The grooves provide a very free exit for the juice and practically eliminate slipping and the consequent mill

vibrations. An unlimited quantity of saturation water may
be used without slipping or reduction of grinding capacity.
The mill inlets and outlets may be very materially reduced in
size, in some instances nearly one-half. These conditions
all tend to an increased juice extraction and also grinding
capacity.

Messchaert [1] states that further improvement in extraction
is obtained by also grooving the discharge or bagasse roll.
These grooves are smaller and more numerous than those in
the feed-roll and are ⅛ inch wide, ¾ inch deep and 1 inch
pitch. Except for these grooves the roll may be smooth.
The top roll must always bear the usual grooves, preferably
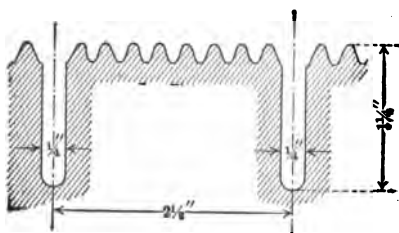
Fig. 8.

about three per inch. The moisture content of the bagasse
is materially reduced by grooving the discharge roll.

Another Hawaiian invention is the Hind-Renton grooving.
This has been tried out in a milling plant that obtained an
average for the crop of over 97 per cent. extraction (sucrose
extracted per cent. sucrose in cane). The pitch is two grooves
per inch and the groove angle is 30° instead of the usual angle
of about 60°. It is claimed that the juice flows out through
the lower part of the groove and that the bagasse wedges
itself above it as a boot in a "boot-jack." It is also claimed
that steel roll-shells may be used with this grooving.

The pressure on the top roll is usually regulated by means
of hydraulic rams, except not generally in Java. Com-
paratively few mills in Java have hydraulic regulation, most

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[1] Report of Committee on Manufacturing Machinery for 1914.
Hawaiian Planters, 12.

of the engineers preferring very slow roll speed and a rigid mill setting.

The hydraulic pressure applied on the top roll varies with the length of the roll, the strength of the mill and the quantity of cane to be ground in a given time. The pressure is also varied with the position of the mill in the series or "tandem." With strong modern mills and rolls 7 feet long about 500 tons pressure and upward is often applied. Practice varies as to the loading, but this approximates 150 to 250 tons hydraulic pressure on the crusher, 425 to 500 tons on the first mill, and from 300 to 450 tons on the other mills of the train. These numbers apply to top rolls 7 feet long. The very high pressure applied to the crusher and first mill prepares the crushed cane to receive imbibition-water, or thin juice from the last mill.

The hydraulic regulation of the top roll has a two-fold purpose, viz., the protection of the mills from serious damage should a piece of metal fall into them or in the event of a too heavy feed of cane, and the regulation of the opening between the rolls to suit variations in the quantity of cane or bagasse passing through them. The hydraulic pressure now carried is so great that a piece of metal may sometimes bury itself in the shell without raising the roll sufficiently to afford protection. Toggles combined with powerful spiral springs are used on many of Mirrless, Watson Co.'s mills instead of hydraulic rams.

The use of very strong cast-steel housings or mill-cheeks has enabled manufacturers to dispense with king-bolts, Fig. 7, or to use very short bolts that extend only part way through the housing (Honolulu Iron Works). This arrangement permits the use of hydraulic rams of large diameter with consequent increase of life in the packing leathers.

The mill "setting" or the adjustment of the openings between the rolls and the relation of the turn-plate to the rolls, varies greatly in different factories and with the rate of grinding and the quality of the canes and the grooving of the rolls. The setting is also somewhat modified when hydraulic-pressure is not used on the top roll, or when it is applied to the bagasse-roll. For the purpose of this chapter, and not as a guide in mill-setting, it is only necessary to give

the openings, etc., of a small milling-plant in Cuba. These
are shown in the diagram, Fig. 9. It may be noted that the
opening between the turn-plate and the top roll is gradually
enlarged from the inlet to the outlet end. Special juice-
grooves are not used in these mills. This enlargement
permits the bagasse to expand after the first pressure and
facilitates the passage of this material and the escape of the
juice. Where juice-grooves (Messchaert) are used, mill-
openings are very much smaller than in the example cited.

The speed at which a system of mills is driven is usually
expressed in feet per minute of the periphery of the rolls.
Practice varies greatly in different countries in regard to the
speed of the rolls. This ranges from as low as 12 feet or less
in Java to as high as over 30 feet per minute in certain
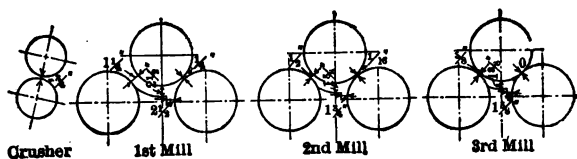
Fig. 9.

Hawaiian plants. The Cuban practice is about an average
of these numbers.

An improvement in mill-accessories of recent years permits
the driving of the cane-elevator or carrier by means of
independent engines instead of from the milling machinery.
Two engines are used to avoid stopping on the centers. This
method of driving the conveyor results in greater uniformity
in the delivery of the cane to the crusher and thus by giving
the crusher and each mill full work at all times it promotes
the extraction of the juice.

Milling-plants are now in operation using from 9 to as
many as 21 rolls in addition to those of the crusher. A favor-
ite combination in large factories consists of 12 rolls and a
crusher, and many engineers consider this number of rollers
about the present economic limit except where a large tonnage
must be passed. These may be driven by one or more engines.
When a very large quantity of cane must be ground, it is

apparently preferable to drive the crusher with one engine, the first, second and third mills with a second and the last mill with a third engine. Electric drive for mills is used in one Cuban factory and apparently with success.

Extraction of the Juice.—Having described the mechanical equipment of the milling-plant, we will now consider the crushing of the cane and the extraction of the juice.

Under the usual conditions, the cane parts with more than 60 per cent of its weight of juice in its passage through the crusher and the first mill. In other terms, upwards of 70 per cent, more in some cases, of the sucrose in the cane is extracted. The woody residue of the cane from the first and subsequent mills is termed "bagasse" by the Americans and "megasse" by the English. As the bagasse progresses through the mills it is compressed more and more, each time parting with some juice, until finally under very superior working conditions it leaves the mills containing 50 per cent of woody fiber.

Few factories conduct their mill work as above without adding water to the bagasse after each mill to dilute the remaining juice and thus increase the extraction. This use of water is termed saturation, imbibition or maceration. These words are usually used synonymously.

Maceration.—The maceration process, properly speaking, is one in which the bagasse is passed through a bath of thin juice or water before regrinding, with a view of diluting the remaining juice. This process is little used and the word "maceration" has come to have the same meaning as saturation, etc.

The saturation may be single, double or compound. The water is sprayed upon the bagasse, in single saturation in a 9-roll plant, as it emerges from the second mill. In double saturation, the water is applied as above and the thin juice extracted by the last mill is pumped back upon the bagasse as it emerges from the first mill. Working with four mills, with single saturation, the water is applied after the second and third mills. Compound saturation may be practised when three or more mills are in the series or "tandem." This method is illustrated in the diagram, Fig. 10. The thin juice extracted by the third mill is pumped back upon the

bagasse from the first mill and that of the last mill upon the bagasse from the second mill. Water is applied to the bagasse from the third mill. The juice from the crusher, first and second mills enters into the manufacture. The application of the water is modified to meet the needs of other combinations of rolls exceeding 12 in number. For example, in the Paia Mill, Maui, H. T., when grinding with their tandem consisting of a crusher and 21 rolls, all the water is applied on the bagasse from the fifth and sixth mills.

Maceration water is sometimes applied to both the upper and lower side of the blanket of bagasse. The application to the upper surface of the bagasse does not usually penetrate the lower layers. It is preferable in applying the water from above to do so just as the bagasse emerges from between
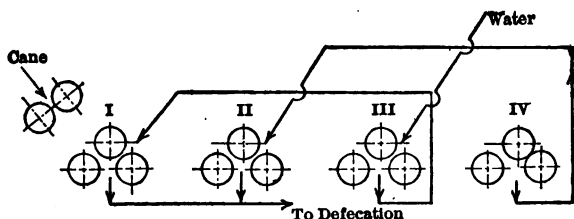
Fig. 10.

the rolls so that it will absorb it in expanding. In this way it acts as a sponge that has been compressed.

The highest efficiency of saturation is obtained in the double and compound processes. There is, however, always danger of fermentation of the thin juice in these methods if the plant is not well arranged for it, hence many manufacturers prefer to use water only, dividing it among the mills. The mills must be shut down at frequent regular intervals for a thorough cleaning where these methods are used. The usual Cuban practice, due to high cost of labor and cheapness of the product, is to grind the largest quantity of cane the mills will pass with good efficiency. This condition prevents thoroughly saturating the bagasse with thin juice as in the double and compound processes, since very wet bagasse

causes the rolls to slip and the mills refuse to receive it. These conditions have improved with the introduction of juice-grooves. Few Cuban factories can spare the time to thoroughly wash down the mills and tanks oftener than once a week.

Tests by many investigators lead to the conclusion that the mill extraction is practically the same whether the maceration-water be used hot or cold. The matter of the quality of the water and some-fuel economy usually dictates the use of warm water. Alkaline water should not be used in white-sugar manufacture. The hot water is derived from the surplus of return water, from evaporator-coils, etc., over the requirements of the steam-plant, and is therefore very pure distilled water. Those of the heat units that pass with the saturation water into the juice are largely economized. There is also a slightly increased evaporation of moisture from the bagasse in transit to the fires, as compared with that obtained with cold saturation. With properly fitted rolls there is little danger of loosening the shell from the shaft by expansion in the use of warm water.

The saturation water never completely penetrates the bagasse. Neither the physical condition of the bagasse nor the time element, *i.e.*, the duration of the contact with the water, permits complete penetration. Manifestly the nearer we approach this ideal condition, complete penetration, the better the extraction of the sugar. Modern mill practice is the reverse of the older methods in which the strongest mills and the heaviest roll-pressures were found in the last mill of the series. The cane is now broken up thoroughly in the crusher, with the expression of as much of the juice as possible, and the heaviest roll-pressure is carried in the first mill with a view to thorough preparation of the bagasse to receive the saturation. The present tendency in milling is to apply the maximum pressure to the first mill that is consistent with its strength and the grinding of the necessary amount of cane, and thus rupture the maximum practicable number of juice-cells. In other words, it is clearly recognized that the bagasse must be thoroughly prepared for saturation. Under these conditions, moderate pressures only are required in the subsequent mills.

If all the juice-cells of the plant are ruptured in the shredding or crushing process and the first grinding, it is evident that when the water is applied to the bagasse, if the time element be sufficient, it will penetrate it and dilute all of the juice it contains.   The time element, however, in practice is so short, and so many of the cells escape rupture, that only the superficial portions of the juice are diluted.

The author has demonstrated by laboratory experiment as follows, that very long contact with water is required for the dilution of all the residual juice in the bagasse: A sample of bagasse from thoroughly crushed cane was heated with water in the proportion of 5 parts of bagasse to 45 parts of water, and the temperature was maintained near the boiling-point one hour.   The water and bagasse were then thoroughly mixed and the dilute juice was strained off, using moderate pressure.   The residual juice was expressed with a laboratory cane-mill, using very heavy pressure, and the two samples of juice were separately analyzed.   The percentage of sugar in the juice extracted by the mill was very perceptibly larger than that in the juice obtained by straining.   This experiment was repeated several times with like results.   Again, in diffusion work with cane, the author has frequently noted that the thin juice obtained by moderate pressure from the exhausted chips contained less sugar than that by heavy pressure.   These experiments show that it is not practicable in milling to dilute all of the juice in the bagasse with the saturation-water, and that a factor depending upon the time element and the efficiency of the mills must be applied in estimates of the water actually utilized.

The following figures are from records of actual milling:

COMPARISON OF MILL-JUICES.

Source of the Samples.	Juice Analyses.		
	Degree Brix.	Per Cent Sucrose.	Coefficient of Purity.
Crusher.	21.4	19.5	91.1
First mill, front roll.	21.2	18.8	88.7
" " back roll.	20.7	18.1	87.4
Second mill, front roll.	18.7	15.8	84.5
" " back roll.	19.8	16.5	83.3
Third mill, front roll.	7.5	6.1	81.3
" " back roll.	9.4	7.5	79.3

Water was sprayed upon the bagasse as it emerged from the second mill. The upper layers of the bagasse were well saturated, but the lower ones received much less water, as the latter was partly absorbed and comparatively little penetrated to the lower layers. It is evident from the analyses that the water did not uniformly dilute the juice in the bagasse.

Influence of the Structure of the Cane on Milling.—The structure has a marked influence on the mill results. With very efficient milling certain canes yield bagasse containing 50 per cent woody fiber (marc) and 45 per cent of moisture; others, when ground with the same mills and mill-setting and apparently the same efficiency, give bagasse containing 45 per cent of fiber and 50 per cent of moisture. These conditions have been observed in Java when grinding the varieties Nos. 247 and 100.

In his study of "The Influence of the Structure of the Cane on Mill Work"[1] Noël Deerr says: "It not infrequently happens that while the fiber remains of constant percentage, the extraction varies largely, the milling conditions remaining the same. Such variation can be readily understood on the assumption that while the total amount of fiber remains the same, its distribution between the pith and rind varies, an increase in the proportion of the latter being accompanied by a decrease in the extraction."

Adhering leaves and the immature tops of the stalks, remaining through careless harvesting, increase the quantity of fiber that must be passed through the mills and adversely affect the extraction. Increased saturation is necessary to overcome this influence.

Efficiency of Milling.—The efficiency of milling is most conveniently expressed in terms of the percentage of the total sucrose in the cane that is extracted in the juice. Numbers between 92 and 95 indicate good efficiency; those above 95 are exceptionally high, and 98 is perhaps the best recorded number in mill-work and is one which rivals results by the diffusion process. The efficiency is also indicated by the numbers obtained in the analysis of the bagasse or by the relation between the fiber and sucrose in this material.

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[1] Bul. 30, Hawaiian Sugar Planter's Expt. Sta., 41.

Straining the Mill-juice.—Three types of juice-strainers are in use, viz.: (1) Hand strainers in which the juice is passed through a perforated-brass plate surface, kept clean by hand work. Such screens are used only in very small factories. (2) Strainers consisting of perforated-brass plates whose surfaces are kept clean by means of flights or slats, similar to a squeegee. The flights are attached to an endless link-belt. They brush the particles of bagasse from the surface of the plates and elevate and deliver them onto the bagasse-carrier from the first mill. The holes in the strainer-plate are round and about 0.04 inch in diameter, or the plate is perforated with about 324 round holes per square inch. If the holes are smaller the plates must be correspondingly thinner and are liable to break. This is the type of strainer that is very generally used in large milling-plants. (3) A recent strainer, patented by Van Raalte, a Dutch engineer in Java, is a modification of the grasshopper sugar-conveyor (see page 102). In this modification, the bottom of the conveyor is composed of brass plates perforated with round holes of approximately 0.02 inch diameter. A canal under the strainer collects the juice. The fine bagasse, "cush-cush" of the English factories, is discharged at the end of the strainer, in a thoroughly drained state, and is returned by an elevator to the mills for regrinding.

The first type of strainer is not to be considered for use in modern factories. The second or drag type has certain advantages and some very marked disadvantages as compared with the others. It strains large quantities of juice with few interruptions and occupies very little space. The wear of the perforated sheets is very great, and in order to use thick sheets the perforations must be larger than would otherwise be necessary. The link-belt soon becomes very foul, and undoubtedly this is a source of sugar losses which escapes consideration, since the chemical control begins with the strained juice. The belt and flights must be frequently cleaned and steamed. The juice-canal and tanks under this strainer cannot usually be conveniently located, thus making it difficult to keep them in a thoroughly sanitary condition. The elevator also fouls quickly from juice-drippings.

The third type of strainer, the "grasshopper," so far as

the writer is aware, is as yet untried outside of Java. A very marked advantage of this strainer is the ease with which it may be kept in a sanitary condition, thus reducing the loss of sugar. Thin sheets with very fine perforations may be used. There is very little wear on the sheets. A straining surface of approximately 2×16 feet is sufficient for 1000 tons of cane per 24 hours. The importance of thoroughly straining the raw juice and its bearing on the manufacture is stated on page 6.

4. Extraction of the Juice by the Diffusion Process.—When the first edition of this book was written, in 1889, there was reason to expect a rapid extension of the diffusion process in the cane-sugar industry. Even at that date this process had very largely superseded presses in the beet-sugar industry. It is now the only process used in extracting the sugar from the beet. The advent of diffusion forced mill-builders greatly to improve their machinery, and, at the present writing, the work of multiple-mills rivals the best diffusion results in extraction. The mills, however, do their work with marked fuel economy. It is largely due to the increased expense for fuel, the large water requirements and the difficulty in disposing of the residual "chips" or bagasse, that diffusion has been almost entirely abandoned. The convenience of milling, with the attendant excellent results by modern mills, has also contributed to the decline of diffusion. In view of these conditions the writer hesitates in devoting so much space to a process that, as regards the cane industry, is almost only of historical interest.

In the diffusion process the cane is cut into small chips or slices, which are packed into cylindrical iron vessels termed "diffusers," or "cells." Each diffuser is provided with strainers at the top and bottom, with a juice-heater and with suitable pipe connections as indicated in the diagram, page 27. The diffusers are arranged in a series and the combination is called a "diffusion battery." The cane-chips are systematically extracted with warm water in these diffusers. The water enters the first cell in the series, filled with chips that are nearly exhausted of sugar, and passes from cell to cell, each containing cane-chips richer than its

predecessor, until it finally fills that containing fresh cane-cuttings. A measured quantity of juice is now drawn off from the last diffuser and is pumped to the defecation-tanks. The first diffuser is now disconnected from the series and the exhausted chips it contains are discharged. The chips containing the least sugar are always in contact with the weakest juice and the richest in sugar with dense juice.

The diffusion process in theory is based upon that property which a certain class of substances possesses, in solution, of passing through a membrane into a contiguous solution. Certain classes of substances pass through a membrane readily and others slowly or not at all. The former substances, which include sugar, are crystalloids and the latter, colloids. The process is termed "dialysis," or, taking into account the direction the crystalloid moves through the membrane, "osmosis" or "exosmosis." The ideal condition for the highest efficiency of this process is that the cane be cut into slices little more than a plant-cell in thickness rupturing few cells, thus permitting the process to be conducted at a low temperature, extracting the greater part of the sugar by dialysis, leaving a considerable part of the impurities in the exhausted residue. This condition can not be even approximated in actual practice and the process usually becomes one of maceration rather than diffusion.

The Diffusion Process. Manipulations.—The first duties of the head batteryman are to see that all joints are tight, that the various signal-bells are in place, and that all mechanical details essential to good work have received attention.

One of the several methods of arranging the valves of a battery is shown in the diagram, page 27.

For convenience of reference we will suppose cell No. 4 is the first to be filled with chips. Fill cell No. 1 with water; when this cell is filled turn the water into No. 2, passing it through two heaters; fill No. 3 in the same manner, heating the water to about 203° F. (95° C.). This assures an abundant supply of hot water for the first round of the battery. Fill cell No. 4 with cane-chips; pass the hot water up through heater No. 3 and down through heater No. 4 and into cell No. 4 at the bottom, driving the air out of this cell through

the vent in the cover. It must be understood that the
supply of cold water in No. 1 is replenished as fast as drawn
upon, through the water-valve of this cell. When cell No. 4
is filled, as indicated by the juice flowing from the air-vent,
close this vent and the valve communicating with the bottom
of the cell by way of the juice-main, and admit the water at
the top of the cell. This operation is termed in this article,
"establishing the pressure at the top of the cell." By this
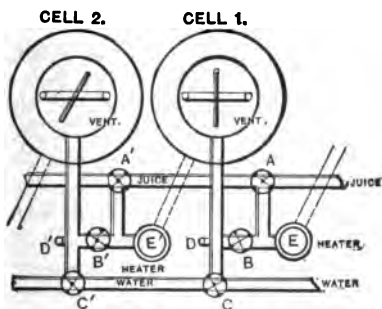
Valve arrangement, etc., of a circular battery built for the U. S.
Government, and located at the Magnolia Station, Louisiana.
  The dotted lines indicate the pipe connection between the bottom of
the cell and its heater; valve A connects the heater with the juice-line;
valve B the heater and the top of the cell; valve C the water-main and
the cell; valve D is for compressed air; E is the heater. In filling a
cell with juice, No. 1 (of the figure) for example, the juice from the pre-
ceding cell passes through the pipe indicated by the dotted lines lead-
ing to E, up through this heater, through A, the juice-line, and A' to
the heater E', down through this heater and the pipe indicated by the
dotted lines into cell No. 1 near the bottom. The air is vented through
the hole in the cover. When the juice flows through the vent, close the
cock, close A and open B. During these operations the valves B', C
C', D, and D' remain closed. With the valves in the positions de-
scribed, to draw a charge of juice open the valve at the measuring-
tank and turn on the compressed air at the cell containing the exhaus-
tion-chips.

time No. 5 should be filled with chips. Draw the juice from
cell No. 4 up through its heater through the juice-main to
heater No. 5, down through this heater and into No. 5 at
the bottom, venting the air as before. It will be observed
that the juice passes through two heaters each time before
reaching the fresh cane-chips. When cell No. 5 is filled
with juice, establish the pressure at the top as before. These
operations are repeated until six or seven cells are filled

with chips. It is now time to make the first draw of diffu-
sion-juice. For example, let us draw from No. 11. Having
filled this cell in the same manner as the preceding ones, the
next manipulation, the pressure being already established
at the top, is to open the valve connecting the juice-main
with the measuring-tank and draw a charge. Having
drawn the requisite amount of juice and having closed the
tank-valve, open that connecting heater No. 12 with the
juice-main and fill cell No. 12 as usual, this cell having
previously received its charge of chips. When cell No. 12
is filled, draw another charge of juice as before. Continue
in this manner, drawing a charge of juice from each cell of
fresh chips. When cell No. 14 is reached, discharge the
water from Nos. 1, 2, and 3 through the waste-valves, the
valve connecting No. 1 with the water-main having been
closed and also that connecting heater No. 4 with the top
of cell No. 5. Connect cell No. 5 directly with the water-
main. Cell No. 4 is now out of the circuit, and the first round
of the battery is completed. If compressed air were employed
in forcing the circulation, as is usual each time a cell of
juice is drawn (except the first round of the battery), No. 4
will have very little water left in it. The next operation is
to open the air-vent on No. 4 for the escape of the compressed
air; or if water-pressure is used, to admit the air to the cell
and permit the water to escape through the waste-valve.'
The door at the bottom of the cell must now be opened and
the exhausted chips discharged into a suitable car or carrier.
The workman on duty below, before latching the door, should
rapidly pass his hand, protected by a cloth, about that part
of the bottom which comes in contact with the hydraulic
joint to remove adhering chips, which might cause a leak.

The first "round" of the battery having been completed,
the regular routine commences. Three cells should always
remain open—one filling and one being prepared for fresh
chips. Every time a cell is filled with fresh chips and juice
a charge must be drawn and a cell of exhausted chips rejected.
In regular work it is usual to designate the cell first in the
series, i.e., the one which receives the water direct from
the supply-tank, No. 1, and that from which the juice is
drawn, No. 10 or 11, according to the number of cells com-

posing the battery. In the above description of the battery
routine nothing was said in regard to the temperature to
which the juice should be heated. The following table shows
the temperature at which the United States Government
experiments were conducted in the work at Magnolia Planta-
tion.

Cell number.....	1	(2 3 4 5 6 7)	8	9	10	11	12
Temp., Fahr.....	140°	158°–176°	203°	203°	203°	185°	160°

In subsequent work, using the Hyatt cane-reducer, much
lower temperatures were required. The dilution of the
juice was no greater than with milling and saturation, and
but 0.07 per cent. of sugar was left in the exhausted chips.

The high temperature of the diffusers in this work was
necessitated by the coarseness of the chips. In the earlier
experiments, in which the cane was sliced, not shredded,
much lower temperatures were maintained with a satis-
factory extraction.

In many batteries the juice is heated by injecting steam
into the circulating pipes. This method of heating modifies
the manipulations slightly, and eliminates the risk of loss
of sugar through leaky heaters.

Prinsen-Geerligs [1] advises the following procedure: "The
most advantageous way of heating is by steaming the diffuser
filled with fresh chips to a temperature of 75° C., and not
warming the others. At this temperature the cells die
and the sucrose diffuses, whilst the albumen coagulates.
After the diffusion-juice is drawn off, its place is taken by
juice which has been in contact with previously heated
chips and hence has a lower temperature, and this goes on
until the exhausted chips leave the diffusion-battery with
the same temperature they had when entering it, so that
in the chips no heat becomes lost."

In order to obtain a maximum extraction with moderately
coarse chips and at the same time a juice of a maximum
density, it is necessary that the temperature of cells 9, 10,
and 11 be kept as high as is practicable. The hotter the
water entering the cell containing the fresh chips, the better

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[1] Cane Sugar and the Process of its Manufacture in Java, p. 25.

the extraction in this cell, and consequently the less work
for the subsequent portions of thin juice which enter this cell.
It is a well known fact that the greater the difference in
the densities of the thin juice bathing the chips and the
heavier juice contained in them the more rapidly the diffu-
sion will take place. Due consideration should be had, how-
ever, for the effect of high temperatures upon the quality of
the juice in deciding upon a maximum.

With a constant percentage of sucrose in the normal
juice, a uniform draw, and a perfectly regular extraction,
the dilution, and consequently the per cent sucrose in the
diffusion-juice, will vary considerably. This variation is
due to the variable juice-content of the cane. In ordinary
seasons (in Louisiana) the per cent juice in plant-cane will
average about 91, and in stubble (rattoons) 89; consequently,
if we draw the same amount of juice when diffusing plant-cane
as we do with stubble, the dilution will be lower and the
analyses of the two juices will vary, even though the normal
juices contained the same per cents of sucrose. It is safe
to commence work with a dilution of about 23 per cent,
estimating on an average of 90 per cent of juice in the cane.
If the extraction is satisfactory but the density of the diffu-
sion-juice too low, the cane contains less than 90 per cent
of juice, and the draw should be decreased until a satisfactory
density is obtained. With thin chips and regular work
the dilution may be reduced to 18 per cent, but it is not
safe to go below this limit except when there is a careful
chemical control to promptly detect and remedy a poor
extraction. With the best multiple effect evaporation it is
economical to burn more coal to evaporate additional water,
rather than leave two or three tenths per cent of sucrose
in the chips which might have been obtained by a little
higher dilution.

The following table, designed for preliminary work, gives
the dilution for different quantities of juice drawn. It is
based on an assumed juice-content in the cane of 90 per cent,
and of an average density of 16° Brix (9° Baumé, or 1.0656
specific gravity).

APPAR-ENT DI-LUTION.	DIFFUSION-JUICE DRAWN PER 100 POUNDS OF CANE.			APPAR-ENT DI-LUTION.	DIFFUSION-JUICE DRAWN PER 100 POUNDS OF CANE.		
	Weight.	Volume.			Weight.	Volume.	
P.C.	Pounds.	Gallons.	Liters.	P. C.	Pounds.	Gallons.	Liters.
10	99.0	11.2	42.3	21	108.9	12.4	46.9
11	99.9	11.3	42.7	22	109.8	12.5	47.2
12	100.8	11.4	43.1	23	110.7	12.6	47.6
13	101.7	11.5	43.5	24	111.6	12.7	48.0
14	102.6	11.6	43.8	25	112.5	12.8	48.4
15	103.5	11.7	44.2	26	113.4	12.9	48.8
16	104.4	11.8	44.6	27	114.3	13.0	49.1
17	105.3	11.9	45.0	28	115.2	13.1	49.5
18	106.2	12.0	45.3	29	116.1	13.2	49.9
19	107.1	12.2	46.1	30	117.0	13.4	50.6
20	108.0	12.3	46.5				

5. By-Product of Milling and Diffusion.—The by-product of milling cane is bagasse or megasse (English colonies), the woody fiber of the cane with the residual juice and moisture derived from the saturation-water. This material supplies a very large part and in many instances all the fuel required by the factory. The exhausted chips from diffusion are dried in Egypt by flue-gases and supply a considerable part of the fuel.

It has frequently been urged that these materials be utilized in paper manufacture. Two or three mills we·e built for this purpose, but were operated only a short time. It was hoped that such utilization of exhausted chips would lead to the commercial success of the diffusion process.

Havik [1] was commissioned by the Government of the Dutch East Indies to investigate the fibers of Java and the other islands with a view to paper manufacture. He obtained 32 per cent of the weight of dry bagasse in dry unbleached paper. The bagasse was from Cheribon cane. The frequently stated yield of 52 per cent of paper is disproved by Havik's experiments.

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[1] Int. Sugar Journ., **14**, 52.

STEAM PLANT AND FUEL

6. Steam Boilers and Fuel.—The boiler capacity required in a cane-sugar factory varies with the manufacturing equipment, the quality of the cane, the quantity of saturation-water and the grade of sugar produced. More boiler capacity is necessary for poor than for rich cane, and for the manufacture of plantation white-sugar than for raw-sugar. If the factory equipment includes multiple application of the vapors generated in evaporating the juice, in juice-heating and for other purposes, as is customary in the beet industry, its boiler requirements are lessened. It is customary to state the boiler capacity required by a factory in nominal boiler horse-power per cane capacity-ton.

A large Cuban factory, having good equipment, including a quadruple-effect evaporator, but not using pre-evaporators or utilizing the vapors from the first or other pans of the multiple-effect evaporator in juice-heating or evaporating sirup, requires from 1.25 to 1.50 nominal boiler horse-power per 1 capacity-ton, or about 12.5 to 15 square feet boiler heating-surface. Good mill-work and the utilization of the vapors of the multiple-effect in juice-heating may materially reduce these numbers. The manufacture of white-sugar with its attendant increase in steam-consumption for evaporating wash-waters, etc., may increase the steam requirements 15 per cent or more.

Both fire-tube and water-tube boilers are used in cane-sugar factories. Many Cuban factories select water-tube boilers on account of their greater safety. The fire-tube boiler is often considered to have an advantage over the other type on account of its large water capacity, which fits it to meet the very irregular demands of the factory for steam.

The usual fuel of the cane-sugar factory is the woody residue from the cane itself, bagasse. Many factories use bagasse as their only fuel, and in many instances this material is produced in excess of the requirements. The modern tendency of applying heavy saturation in milling has increased

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the demand for steam, with the result that coal, wood or oil must often also be burned. Where cane is of moderate cost, labor and fuel very dear and the sugar sells for a very low price, the factory may sometimes bring in larger net returns by grinding a large quantity of cane less efficiently than it could a small quantity. This large grinding produces more fuel in proportion to the radiating surfaces and as it is usually necessarily accompanied by the use of a reduced quantity of saturation-water, extra fuel is often eliminated. This condition frequently exists in Cuba, hence few factories have adopted pre-heaters or use a part of the vapors from the multiple-effect evaporator in heating juices or in evaporation sirup in vacuum-pans.

There are three general types of furnaces used in burning green bagasse for the generation of steam. (1) The first of these was patented by Samuel Fiske, the inventor of the cane-shredder. It was first used in Louisiana and then in Cuba at "Soledad" Cienfuegos. This furnace consists of an oven fitted with horizontal grate-bars upon which the bagasse is burned. A single furnace was often connected by means of flues with several boilers, though preferably in entirely new installations with but two. In the latter case the furnace was under the front end of the boilers. Forced-draft was used in the early installations, since the bagasse often left the mills with as high as 60 per cent moisture. (2) Almost simultaneously with Fiske, Frederick Cook introduced his green bagasse-burner into Cuba at "Hormiguero," also after using it in Louisiana. In this type of furnace the bagasse is burned on a hearth in an oven placed between two water-tube boilers. Air is forced into the burning bagasse through tuyeres. Prior to the introduction of the Fiske and Cook burners all bagasse was sun-dried in Cuba before burning it. The inventions of Fiske and Cook had a profound influence upon sugar-manufacture in Cuba through enabling, and, in fact, forcing the factories to operate day and night instead of but fourteen hours, and in sending large numbers of people to the fields who were formerly employed in drying and firing bagasse. (3) The step-grate furnace is the third and most recent type. In this type there is usually a furnace in front of each boiler. The grates are

inclined and resemble a step-ladder, and in fact are often termed "step-ladder" grates. These grates are very long and narrow. The bagasse falls upon the top steps of the ladder and gradually works its way to the small flat grate at the bottom.

Modern installations of all three types of furnaces are very efficient. The flat-grate is most generally used in Cuba. The step-grates are very efficient with very dry bagasse and are those usually used in the Hawaiian Islands and Java. Forced draft is now little used, since with the vast improvements in milling, the bagasse usually contains 50 per cent and often very much less moisture and gives good results with natural draft.

Fuel Value of Bagasse and Other Residues.—There is great uniformity in the number of heat units (B.T.U.) of perfectly dry bagasse, as has been shown by the results of many calorimeter combustion tests made in various parts of the world. In considering the actual fuel value of bagasse as it is burned upon the grates, it must be taken into account that a certain number of heat units are absorbed in evaporating its moisture and heating the resultant vapor to the temperature of the chimney. Further, a part of the fuel is consumed in heating the excess of air that is drawn through the grates and is carried away with this and an additional quantity also with the products of combustion. Dr. R. S. Norris [1] published the following figures for Hawaiian bagasse of various degrees of moisture:

Per Cent Moisture in the Bagasse.	Fuel Value per Pound of Bagasse, B.T.U.
42	3129
43	3057
44	2982
45	2909
46	2835
47	2762
48	2687
49	2614
50	2540
51	2468

[1] Bul. 40, Hawaiian Sugar Planters' Expt. Sta.

This table may be used in comparing different bagasses and also bagasse with other fuels, using the fuel values of the latter.

The thermal value [1] of dry cane-trash as determined by Norris (*loc. cit.*) approximates 4322 calories per kilogram of dry matter. According to the same authority Hawaiian final molasses has a somewhat higher thermal value than green bagasse. In burning molasses it is best applied by atomizing it with steam as in burning crude oil.

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[1] One calorie = heat required to raise the temperature of 1 kilogram of water 1° C. at or near 4° C. (Temperature of maximum density of water) = 3.968 B.t.u.

One British thermal unit (B.t.u.) = heat required to raise the temperature of 1 pound of water 1° F. at or near 39.2° F. (= 4° C.) = 0.252 calorie.

AN OUTLINE OF THE CUSTOMARY METHOD OF MANUFACTURING RAW ·CANE-SUGAR.

Introductory.—The purpose of this outline is to minimize the repetitions in future descriptions and especially to define many of the technical terms, at the same time illustrating them with examples. Terms used elsewhere than in the United States are included in parenthesis. The processes are described in full in a subsequent part of the book.

7. Outline of the Manufacture.—*Purification of the Juice.*—The defecation or clarification of the juice is accomplished by means of lime and heat. The acidity of the juice is neutralized by milk of lime, its temperature is then raised to the "cracking" point, or usually a little below 200° F. In Louisiana practice the scum is often "brushed" off the juice after heating and the latter is then "clarified" by boiling and continued brushing. The greater number of factories using the defecation process settle the juice in special tanks after heating, and decant the clear liquid or "clarified juice" from the "mud," "scum" or "slops" (Cuba = *cachaza*). The mud is filter-pressed and the filtrate or "press-juice" is mixed with the clarified juice. The precipitates retained in the press, "filter-press cake," are used in fertilizing the fields.

Evaporation.—The clarified juice is evaporated in partial vacuo to a "sirup" (Cuba = *meladura* [1]; beet industry = thick juice), containing approximately 45 per cent of water.

Crystallization.—The crystallization is accomplished in single-effect vacuum-pans under reduced pressure. The sirup is evaporated until saturated with sugar. At this point crystals or "grains" separate in the boiling mass. The pan is "charged" with sirup from time to time, as the water evaporates, and the sugar it contains is largely deposited upon the grain present without the formation of additional crystals. Should additional crystals, "false-grain," form

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[1] Pronounce " May-lah-dów-rah."

through carelessness or otherwise they must be remelted to prevent interference at a subsequent stage of manufacture. Finally when the crystals are of sufficient size or the pan has been filled, the mixture of crystals and sirup is concentrated to a dense mass, "massecuite," (beet industry = fill-mass) and the "strike" is then discharged from the pan. This latter is often termed a "strike" pan.

Centrifugaling; Purging; Reboiling Molasses.—The massecuite is conveyed into a mixer and from this is drawn into centrifugal-machines, "centrifugals." These machines have cylindrical perforated metal "baskets," lined with wire-cloth or perforated bronze-sheets and are spun at high velocity. The sugar-crystals are retained by the lining and may be washed upon it with water if desired. The mother liquor, "molasses," passes through the lining by reason of the centrifugal force exerted. The machine is stopped after the removal of the molasses and the sugar is "cut down," leaving the centrifugal ready for another charge of massecuite.

The molasses is reboiled to obtain a second crop of crystals and the "second massecuite" is centrifugaled as before, yielding "second sugar" and "second molasses." This molasses is also reboiled and yields "third sugars" and "final molasses," "black strap" or "third molasses."

The processes followed in the modern factory are more complicated than is here indicated. At a certain stage of the "pan-boiling" molasses is injected into the pan instead of sirup or is said to be "boiled-in" or "boiled-back" and it thus increases the output of high-grade sugar. In fact the modern factory usually produces but one grade of sugar and final molasses.

Factory Design and Construction.—A large Cuban factory of recent construction, designed and erected by B. Glathe, Chief Engineer of The Cuban-American Sugar Company, is shown in the Frontispiece. This factory has two tandems or trains of mills. It is so arranged that its capacity may readily be doubled or even further increased by adding a mill-house at the left and extending the boiling-house at the right. The present annual capacity of the factory is approximately 80,000 tons of sugar. The buildings are of steel, and the machinery is largely electrically operated.

MANUFACTURING PROCESSES.

PURIFICATION OF THE JUICE.

8. Purification of the Juice. General Considerations. — The juice is first thoroughly strained as has been described on page 24. The next step is dependent upon the class of sugar that is to be made. Lime and heat are the agents used almost exclusively in raw-sugar manufacture. In the simpler methods of making plantation white and high-grade yellow sugars, sulphurous acid is used in conjunction with a small quantity of lime. In these processes the lime is added to neutralize or partly neutralize the acids of the juice and that of the added acids if any, and heat is then applied to a temperature a little below 94° C. (201° F.). A heavy precipitate is thrown down and thick scum rises to the surface of the juice. The albuminoid matters are coagulated and largely rise to the surface, and the acids combine with the lime to form soluble and insoluble salts. The fat and wax and part of the gums are included in the scum. The clean juice is separated by subsidence and decantation. This is termed the defecation process, or in some localities the "clarification" of the juice.

A modification of the carbonation process of the beet-sugar industry as regards temperature and liming conditions is frequently used in combination with sulphitation in the manufacture of plantation white sugar, notably in Java.

An identical carbonation process was worked out about 1886 by the U. S. Department of Agriculture [1] in experiments with sorghum in Kansas and sugar-cane at Magnolia Plantation, Louisiana. Possibly the process originated in Spain. A sulphitation process devised by Bach, in Java, differs from the usual one in the addition of the lime at two stages, viz.: to the juice and the sirup (concentrated juice), each

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[1] See report of the Bureau of Chemistry.

addition of lime being followed by sulphitation. Both juice and sirup may be filtered or the precipitates may be separated by decantation.

The above processes and slight modifications of them are those used almost exclusively in the cane-industry.

A recent patented process for white sugar, by Wijnberg, differs from all others in using a decolorizing carbon of great bleaching power called "Norit." The carbon is added to the slightly acid defecated juice, which is then boiled and filter-pressed. The carbon (press-cake) is revivified by boiling with a 5 per cent solution of caustic soda and occasionally by reburning it in a kiln. The sirup is filter-pressed with kieselguhr.

A process, differing radically from the others, has been patented by Batelle and worked upon an experimental scale. The glucose of the juice is destroyed by the action of lime at boiling temperature. This enables the use of the Steffen saccharate-of-lime process in the recovery of the sugar from the molasses. The saccharate is used as in beet-sugar manufacture in liming the juice. After heating to decompose the glucose the juice is carbonated and sulphited as in the carbonation factories of Java.

A very large number of substances have been used by many experimenters in purifying beet- and cane-juices. Von Lippman's list of these, comprising more than 600 entries, is given on page 532.

In none of the processes for the purification of the juice is the high temperature maintained long enough to destroy spores, hence care is necessary to avoid decomposition at later stages of the manufacture.

9. Defecation and Clarification with Open Tanks. —This is the process in general use and has been practised since the early days of the cane-sugar industry, with little improvement until recent years.

The raw juice is pumped from the mill-tanks to double-bottomed vessels termed "defecators." The inner bottom of the defecator, is of copper and the outer shell of iron. As soon as the bottom of the defecator is covered with juice, milk of lime is added to it to neutralize the acids and steam is turned into the space between the bottoms.

The workman regulates the steam-pressure so that by the time the defecator is filled with juice the latter will have nearly reached its boiling-point. The moment the thick scum that covers the surface "cracks" the steam is shut off and the juice is left undisturbed for the subsidence of impurities.

If the quantity of lime required has been properly gauged, as will be described farther on, a part of the impurities rise to the surface with the scum, forming the "blanket," and a part settle to the bottom of the defecator.

The action of the heat coagulates the albuminoids and the lime forms insoluble and soluble salts with the acids of the juice. The heavy precipitate in settling and the scum in rising carry with them the impurities separated in the defecation, leaving a thick deposit of mud at the bottom of the defecator, a blanket of scum at the surface of the liquid, with bright, clear juice below it.

When the temperature of the juice rises in the defecator and the blanket breaks, in the efforts of the air and gases to escape, it is said to "crack."

Several defecators are usually arranged in a series and are filled with juice in regular order. Allowing sufficient time after the "cracking" for settling, the mud is drawn off from the bottom of the defecator and the sent to the filter-presses, the clear juice is run into the evaporator charge-tanks or into clarifiers, and finally the scum is sent to the presses.

The proper liming of the juice requires considerable skill. If too little lime is used, the impurities settle slowly, the clarified juice lacks brilliancy, and the subsequent boiling of the sirup and purging of the sugar are impeded.

A juice limed to neutrality to litmus also usually settles slowly. The precipitate settles rapidly, with slight over- or under-liming, leaving a bright juice. In the manufacture of raw sugar the lime should be added so long as it produces a precipitate, but no more should be used. In making certain dark-colored sugars, however, more lime is used than is required for the clarification of the juice. This is undoubtedly prejudicial to the yield of sugars.

In the manufacture of white or yellow clarified sugar,

using sulphurous acid, the juice should be limed nearly to neutrality to litmus paper.

The appearance of the juice and the blanket and the motion of the suspended matter as observed in a glass test-tube are usually sufficient guides for an experienced defecator man. The particles of suspended matter should move rapidly toward the surface of the liquid at the sides of the tube, and descend promptly at the center, forming a compact cone. These tests may be supplemented, in daylight, to advantage by the use of very sensitive litmus paper.

The quantity of lime required in the defecation may be ascertained by a titration of the juice with a standardized calcium saccharate solution or other acidimetric methods. Such methods are usually employed in raw-sugar work only occasionally and then in a laboratory control.

In conducting the work of the factory, the sugar-maker adds such quantity of lime to the juice as his experience indicates to be approximately correct; two or three defecators may have been filled before he can heat the first and from it, by the eye only, gauge the lime for the others. By means of litmus paper, in daylight, he can test the juice in the first defecator, immediately it is filled, and from this test modify the alkalinity of subsequent portions of juice, until the liming is properly adjusted. As the changes of litmus paper can not be well observed except by daylight, a slightly acidulated phenolphthalein solution may be used in testing a few drops of juice in a white saucer. The color reaction is plainly visible by artificial light.

In liming juice to alkalinity, in raw-sugar work, samples of defecated juice, filtered through paper, should be tested from time to time with a solution of saccharate of lime, in a test-tube. If a precipitate is produced by the saccharate, more lime should be used in the defecation, and, vice versa, if there is no precipitate, the lime should be reduced.

It is the usual practice in Louisiana to use the same tank, fitted with coils and not a steam-jacket, as both a defecator and clarifier. The defecation is accomplished as above except that the blanket is immediately removed and the juice is then boiled briskly, the workman at the same time "brushing" off the scum that rises. This latter part of the process

is properly termed the "clarification," though in Louisiana
this word is applied to the entire process.

In addition to the defecation process as already described,
clarifiers or eliminators are frequently used. The ordinary
clarifier is a tank fitted with steam-coils and a mud-gutter.
The clear juice is drawn from the defecators into the clarifier,
where it is boiled and skimmed and is then run into settling-
tanks.

The English eliminators differ from the ordinary clarifier
in having a steam-manifold, with the steam-inlet and water-
outlet so arranged that the scum is thrown to one side of
the tank into a trough, and the juice requires no hand-
labor in skimming it. This method avoids boiling the
mud from the defecation with the juice while clarifying.
In the elimination process a total boiling during one minute
is usually sufficient.

It sometimes occurs that the impurities separated in the
clarification will not settle promptly in the settling-tanks,
or subsiders. This may be due to the condition of the cane,
but usually arises from the admixture of sirup tank-bottoms
with the juice in the clarifiers. Thorough agitation of the
upper layers of juice with a long-handled paddle or other-
wise, or liberal spraying of the surface with cold water, will
usually cause the impurities to promptly settle. Cold water
is more effective than stirring of the juice. The rise of the
scum to the surface is probably due to the presence of gases.

A modification of the defecation process consists in boiling
the juice and scums, instead of only heating them to the
cracking-point, and running them into settling-tanks. All
of the separated impurities settle to the bottom of the
tank, no scum remaining on the surface of the juice.

In connection with the diffusion process the defecation
is sometimes accomplished in the diffusers. The requisite
quantity of lime is added to the cane-chips on their way to
the battery, and the diffusion is conducted at a high enough
temperature to coagulate the albuminoids. The cane-
chips act as a filter, retaining all of the impurities separated
in the defecation, hence neither defecators nor filter-presses
are required.

Sulphurous acid-gas is used in Louisiana in raw-sugar

manufacture to saturate the juice prior to liming. When used in tropical work the liming is usually followed by the sulphitation.

10. Defecation Using Closed Heaters and Open Settlers.—The large increase in recent years in the capacity of factories using modifications of the ordinary defecation process (**9**) has led to the use of heaters and very large defecators. With a suitable installation this method is very efficient, both in its economics of fuel and labor, and the purification of the juice.

The juice is first limed in the cold in a series of large tanks. At least three conical-bottomed tanks should be used, that each may be thoroughly cleaned after each filling. The lime precipitates are kept in suspension by rotating paddles or by a current of air forced through a perforated pipe. The latter is the preferable method, as the pipes interfere but little in cleaning the tanks.

The juice is pumped from the liming tanks through closed heaters containing a large number of copper tubes. Approximately 1 square foot of heating surface per 1 cane capacity-ton is required in the heaters. Where heating capacity permits, exhaust-steam is used in these heaters. The temperature of the juice should be raised to a little below the boiling-point.

The heaters deliver the juice into large settling-tanks. In many factories, these tanks are not provided with heating-coils and the juice is simply settled and drawn off from the mud. The writer's experience indicates that much better results are obtained by the use of coils to reheat the juice to the "cracking-point" before settling.

The actual average working-depth of the tanks should not exceed 6 feet. The greater the depth of the liquid the longer the time required for the settling of the precipitates. The bottom of the tank should slope sharply from the rear end toward the front and from the sides to the center. The slope from rear to front should be at least 1 inch per foot, and preferably greater. This incline is necessary to facilitate the removal of the precipitates (mud, scum or cachaza). The juice and steam should enter the tank at the rear. The clear juice and mud should be drawn off at the front. The

juice entering the tank at the rear tends to carry the mud for-
ward toward the outlet. The coils should be of copper and
about 4 inches in diameter and should provide approx-
imately 25 square feet of heating surface per 1000 U. S.
gallons of actual juice capacity in the tank. The coils
should be well above the bottom of the tank to facilitate
the removal of the mud.

The writer prefers a rectangular defecating tank, with
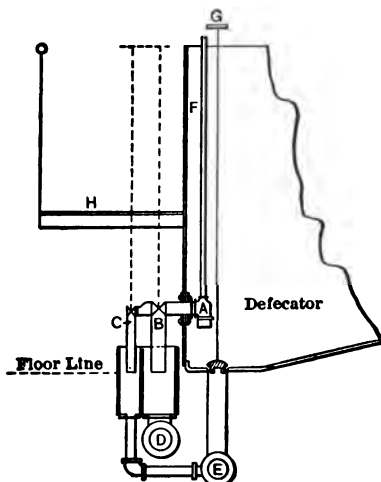
FIG. 11.

rounded corners and the draw-down arrangement described
below. These tanks may be of very large capacity. Many
now in use have a working capacity in excess of 6000 gallons.
While a deep tank requires a rather long time for settling,
it has the advantage of yielding a small proportion of mud.
In so far as possible, it is preferable that the juice be con-
veyed from the defecators through pipe-lines rather than
canals.

The draw-down arrangement is shown in Fig. 11. At *A* is a
side outlet-elbow, with a ventilating pipe, *F*, leading above the

top of the tank. In drawing down, the juice flows through the nipple, the elbow, A, and the cross valve, B, into the small collecting-box and thence to the trunk line, D. The angle-valve, C, is opened for a moment before drawing down the juice, for the removal of mud that may have settled in the pipe-line or that may be near the outlet-nipple. The valves, B, C, are controlled from the working-platform H. The valve G is used in washing the mud into the main line to the scum tanks, E. It will be noted that the pipe is ventilated to prevent syphoning and that the juice therefore stops flowing when its level reaches that of the bottom of the draw-down pipe and no mud can be drawn down. The elbow and nipple insure that juice shall be drawn from below the scum. It is advisable to locate about three or four draw-down pipes in each defecator, with difference of level of about 4 inches, measured between centers. The lowest pipe should be about 12 inches above the bottom of the tank. The draw-down pipe should be about 3.5 inches in internal diameter in a defecator of 4000 gallons working capacity. If the juice has been properly limed and heated, there is no probability of drawing down mud, provided a sufficient settling time is allowed. Ample tank capacity and proper supervision of the liming are essential. Eight 5000-gallon tanks are sufficient for a grinding capacity of about 1400-1500 tons of cane per day.

11. Defecation Using Closed Heaters and Closed Settlers. Deming's Process.—This process was invented by M. A. Scovell in a sorghum-sugar factory. The patents were purchased by Deming, who developed the process and made it available in practical work. This method is adaptable to factories of all capacities.

The juice is limed in the cold in Deming's process, in a single constant-flow tank. Milk of lime flows into the juice at the heater-pump intake and is thoroughly mixed with it in the pump and in transit to the heaters. The limed juice is heated to approximately 235° F. and is then passed into an eliminator, where it parts with the gases, is slightly concentrated, and warms the incoming cold juice on its way to the heater. The eliminator is a cylindrical closed-iron-vessel with a conical bottom and is provided with a large heating-surface in copper tubes. Cold juice circulates

through the tubes and condenses the steam set free when the hot juice enters the lower section of the eliminator. A partial vacuum is produced by this condensation and the air and other gases are withdrawn from the hot juice. The upper part of the eliminator is connected with a pump or the vacuum system.

The temperature of the juice should be reduced to about 210° F. in the eliminator. From here it is pumped into the outer compartment, A, of the closed settler or pressure-separator, shown diagrammatically in Fig. 12. The mud is drawn off continuously from the conical bottom of the tank at C and the clear juice is discharged from the central cone, B. In many factories using Deming's heaters and settlers, the juice is heated to only 212° to 218° F.
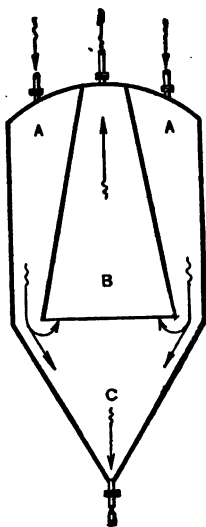
In his first experience with these tanks, the earliest of their type in Cuba, the writer noted that the mud drawn off after several hours' operating had an offensive odor, indicating decomposition. He immediately installed very slowly moving scrapers in the tanks to prevent the mud from settling on the conical bottom of the separator and thus nearly eliminated decomposition. Certain spores resist the high temperature of the heater and cause the decomposition. In Cuban practice it is found necessary to liquidate and clean the tanks as often as may be practicable. (See **35.**)

FIG. 12.

11a. Cleaning the Heating-surfaces of Defecators. The heating-surfaces of juice-heaters and defecators usually soon become incrusted with scale, impairing their efficiency. The copper-surfaces of the ordinary double-bottom defecators are usually kept clean by washing with water and scrubbing them after each use. Long-handled brushes, made of maize husks, are used in Cuba in this work. It may occur in some

localities that the laborers are unwilling to clean the defecators with brushes. In this event, the copper bottom should be covered with water strongly acidulated with hydrochloric acid and the solution boiled. Five to six pounds of the commercial muriatic acid are usually sufficient for use in cleaning a 1000-gallon defecator.

The heating-surfaces of coil-defecators used in combination with juice-heaters foul but little. Those in which the whole defecation process is conducted require frequent cleaning. Dilute muriatic acid is used in cleaning, as in the ordinary double-bottom defecator. When the coils are very much scaled, these may be cleaned by drawing a light chain over the surface.

Juice-heaters usually foul very quickly. The usual method of cleaning is to circulate hot caustic-soda solution through the tubes and follow this first with water and then with hot dilute muriatic acid. The soda solution may be returned to a storage-tank for repeated use, decanting it from the mud and adding caustic soda from time to time to maintain a strength of about 1 pound of soda to 7 gallons of solution. Occasionally the scale in the tubes is of a very resistant nature and must then be removed by scraping the surfaces. If the tube area is properly adjusted to the volume of the juice, so as to force a very rapid current, the scaling is much reduced.

DEFECATION IN WHITE-SUGAR PROCESSES.

12. Sulphitation Process of Louisiana.—This is one of the simplest of the sulphitation processes and when skillfully conducted produces a very good, though irregular, quality of "near-white" or "off-white" sugar.

The cold raw-juice is pumped through a sulphur-tower or box, in opposite direction to and through a current of sulphurous acid gas. The juice should absorb as much of the gas as is possible. This sulphitation is followed by liming to very slight acidity to sensitive litmus paper and the juice is then heated, settled and decanted, as is usual in the defecation process. The juice is usually reheated to boiling and then brushed before settling. Evaporation to sirup follows. Many factories boil and brush the sirup also. This brushing

is a wasteful process, since it entails large consumption of fuel and loss of sucrose. Heating to the boiling-point is sufficient. The concentrated juice is also sometimes sulphited.

This is a very old process, and possibly originated in the English or French colonies. It is interesting to note that it has always been the custom to work the juice faintly acid to sensitive litmus to prevent coloration of the sugar. This condition corresponds to the essential one of the recent Java acid thin-juice process.

Reserve (Louisiana) White-Sugar Process.—The raw juice is very strongly impregnated with sulphurous acid in a vertical cast-iron sulphuring-box of the cascade type. The box is cylindrical, 3 feet in diameter by 26 feet high. This box has sufficient capacity for 2000 tons of cane per 24 hours. The sulphured juice flows from the box into the liming-tanks, where milk of lime is added to it in sufficient quantity to reduce the acidity to the equivalent of 1.2 cc. of N/10 soda per 10 cc. of juice, using phenolphthalein as an indicator. The juice is next heated in a tubular heater to 212° F. and it then flows through Deming's continuous settling-tanks. The hot juice should have an acidity to phenolphthalein equivalent to .85 to .9 cc. of N/10 soda per 10 cc. of juice, and is then strictly neutral to litmus. Phosphate of soda is added to the juice flowing into the settling-tanks at the rate of 1 pound per 1000 gallons of juice. This phosphate of soda is especially prepared for the purpose and has the same acidity as that of the juice. No lime is added to the mud preparatory to filter-pressing. The filtrate from the presses is added to the juice flowing from the settling-tanks and the whole is passed through bag-filters. The acidity of the juice remains equivalent to from .85 to .9 cc. N/10 soda per 10 cc. of juice. This is not sufficient for a high-grade sugar, hence the juice is again sulphited and the acidity is raised to 1.2 cc.

The clarified juice is evaporated to a sirup of 54.3° Brix. The sirup is perfectly bright and its color is a dark yellow. There is no further precipitation if heated to the boiling-point. The sirup is boiled to massecuite, as is customary in white-sugar manufacture.

The high acidity of the juice as compared with that in Harloff's work is quite noticeable. As previously stated, this is usual in Louisiana practice.

13. Sulphitation after Liming.—This process differs from the preceding in adding the lime, in large excess over that required to neutralize the juice, before sulphitation. Approximately 8 gallons of milk of lime of 26.5° Brix is used, thus producing a very heavy precipitate with the sulphurous acid and which may be readily removed by settling and decantation. If a larger quantity of lime is used, e. g., 10 to 12 gallons, the precipitate may be removed by filter-pressing. The sulphitation is continued to neutrality to phenolphthalein. The decanted or filter-pressed juice, after concentration to sirup, is usually cooled and sulphited to slight acidity An acidity equivalent to that required in 10 cc. of sirup to neutralize 25 to 30 cc. of 100th normal alkali is a suitable amount.

Bach's Sulphitation Process.—This process is extensively used in Java, under the patents of its inventor, A. H. Bach. Lime is added and is precipitated by sulphurous acid at two stages, each followed by subsidence and decantation or by filter-pressing. Very little if any more lime is used than in the process described in the preceding paragraph.

From 5 to 7 gallons of milk of lime of 26.5° Brix is added to each 1000 gallons of cold raw juice. This is then sulphited to neutrality to phenolphthalein and finally heated to full boiling, settled and the clear juice decanted as in the ordinary defecation. The clear juice is evaporated to the customary density, approximately 55° Brix.

The sirup obtained as above described is passed through a cooler and its temperature is reduced to about that of the factory's water supply. From 16 to 17 gallons of the milk of lime per 1000 gallons are now added to it and it is then sulphited to neutrality to phenolphthalein, or the full quantity of sulphurous acid in solution may be added to the sirup prior to the lime. Since the volume of the sirup is about 30 per cent of that of the original juice, the total volume of milk of lime used per 1000 gallons of juice is from 10 to 12 gallons. Steam jets are used to beat down the foam during the sulphitation. The sulphited sirup is heated to about 194° F.

(90° C.) and is filter-pressed. The press-cake is washed with water in the press and a large part of the sugar it contains is recovered. The filtration is rapid and the cakes are firm and well formed.

The filtered sirup contains some bisulphite of lime and is therefore heated to about 195° F. to decompose this and other bi-sulphites. The heated sirup is usually run into settling-tanks, and after the deposition of the precipitates the clear liquor is decanted and cooled as previously, and is then sulphited to distinct acid reaction to phenolphthalein and is then ready for the vacuum-pan.

Bach's process is sometimes slightly modified by separating all of the precipitates by decantation and mixing and filter-pressing them together.

This process requires approximately 0.055 per cent of sulphur on the weight of the cane. The sugars are of good quality.

CARBONATION PROCESSES.

14. Preliminary Remarks.—The ease with which cane-juices yield to the ordinary defecation and sulphitation processes has retarded an extension of the carbonation process, even in Java, where it has its largest application. The U. S. Department of Agriculture conducted extensive experiments on a manufacturing scale with carbonation of sorghum-juices in Kansas and cane-juice in Louisiana, nearly thirty years ago. The writer was active in this experimental work with Dr. H. W. Wiley, then Chief of the Bureau of Chemistry. As the Government reports show, these experiments were satisfactory from a manufacturing, but not financial point of view. They brought out the necessity of carbonation at temperatures well below 60° C., as is now practiced in Java, though this possibly originated with the French in the early Spanish installations.

There are two distinct carbonation processes, viz.: the single, in which all the added lime is saturated in one operation, and the double carbonation, in which the juice is treated twice with the gas. In the double process, a part of the lime is carbonated and removed by filtration and this is followed by a second carbonation in which the remaining

lime, or this and a small additional quantity, are completely saturated with carbonic acid gas.

The single process has been materially and successfully modified by J. S. de Haan, thereby reducing the quantity of lime required and the expense of the process.

15. Single Carbonation.—A quantity of lime in the form of a milk and varying somewhat with the quality of the cane, is added to the cold raw juice. This quantity of lime is approximately 1 per cent of quick-lime in terms of the weight of the cane. The facility with which the carbonated juice is filter-pressed is the principal factor in determining the quantity of lime. Dry lime should not be used, as is frequent in beet-sugar manufacture, on account of the decomposition of the glucose, but the lime should be thoroughly slaked and efficiently strained through fine wire-sieves. Failure to carefully slack the lime and strain the milk may result in fine particles of quick-lime passing into the juice. The carbonic-acid gas attacks the surfaces of these particles and does not penetrate them. The superficial layer of carbonate thus prevents the carbonation of this occluded lime and leaves it to complicate the end-reaction and decompose glucose, and thus darken the juice, when heated. The juice is usually limed in the carbonation-tank. The single carbonation is an intermittent process, *i.e.*, the tank is completely emptied after each operation.

The older forms of single and first carbonation-tanks were comparatively shallow, having perhaps from 4 to 6 feet of depth above the juice-level. It is necessary with these shallow tanks to use various expedients, such as steam-jets, jets of carbonic-acid gas, or oil upon the surface of the juice, to reduce the foam which forms in large quantities at a certain stage of the process. The tanks for the single carbonation and the first carbonation in the double process in modern installations are very deep, often exceeding 22 feet in depth. The tank is usually filled to less than one-fourth its depth. Pipes leading above the factory roof are provided to carry off the surplus carbonic acid. These tanks are usually provided with steam heating-coils.

Having limed the juice, carbonic acid is forced into it near the bottom of the tank. The gas attacks the lime

forming the carbonate and then forms sucrocarbonates of lime and renders the juice very viscous. It is at this stage that foaming begins and it increases with the increase of sucrocarbonates. There is always danger of forming dark-colored decomposition products with the glucose when steam is used to beat down this foam. Further there may be excessive rise of temperature, which will later be shown to be very objectionable. The carbonic acid gradually combines with the lime. The sound made by the bubbles of gas in the juice and the violence of the frothing are indications to the attendant of the progress of the carbonation.

The temperature gradually rises during the progress of the carbonation. During the early stage the temperature should approximate 45° C. and should nearly reach 55° C. when all the lime is precipitated. When steam is not used to reduce frothing, the rise is not sufficient for the final stage of the process. Therefore, when neutrality of the juice to very sensitive phenolphthalein paper is nearly reached, steam is turned into the heating-coils and the temperature is gradually raised to 55° C. Finally when the phenolphthalein paper (Dupont paper) indicates neutrality the juice is heated to 70° C. It is necessary to raise the temperature in order to break up the sucrocarbonates and to facilitate filtration of the juice. The attendant may note approaching neutrality by the "spoon test," i.e., the appearance of the juice held in a spoon. The precipitates separate sharply from the juice when the latter has an alkalinity equivalent to approximately 0.04 per cent calcium oxide or as often stated 0.4 gram lime per litre. The expression "equivalent" is used here because the alkalinity is partly due to potassium and sodium hydroxides, formed by the action of the lime upon the sodium and potassium salts of the juice. The spoon-test must be followed by frequent tests with the phenolphthalein paper (Dupont paper) until neutrality to this paper is reached. The juice is then heated to nearly 70° C. and is over-carbonated during a very few seconds to neutralize the slight alkalinity arising from lime that has not been attacked by the carbonic acid. In practicing the carbonation process on beet-juices allowance must be made for alkalinity other than due to lime, to avoid over-carbonating. This is not

usually necessary in cane work, but it is advisable to make occasional tests for potash alkalinity to be prepared to correct for it.

The next stage of the process is the filter-pressing. The filter-presses are dressed with heavy cotton-cloths as in the defecation process. Thin cotton-cloths are usually placed over the heavy cloth to protect it from wear. Three suits of heavy cloth are usually consumed per five suits of the thin. Steam is turned into the press before use and is not shut off until it escapes freely from the juice-cocks. The object of this steaming is to destroy bacteria, which, on account of the low temperature of the material to be filtered, would otherwise be very active in destroying sugar.

The carbonated juice is pumped into the presses at pressures up to about 45 lbs. and should filter very rapidly. The juice should flow very freely from the cocks and the press-cake should be firm and granular. Contrary conditions, sluggish filtration and a pasty press-cake indicate the use of too little lime or an imperfect carbonation. The work of the filter presses is the best indication of correctness of the manipulations. The filter press-cake is usually washed in the press to a low sucrose content. (*See* under filter presses, page 67.)

The filtered juice is sulphited, concentrated, etc., as in the sulphitation process.

De Haan's Single Carbonation Process.—This important modification of the carbonation process is due to J. S. de Haan, Klaten, Java, and is in use in several factories under his technical direction.

This process reduces the consumption of lime and simplifies the equipment without sacrificing the quality of the sugar product. The alkalinity of the juice is kept within very moderate limits during the carbonation.

The raw juice is heated to 45°–50° C., and then a small stream of milk of lime and the carbonic-acid gas are simultaneously turned into it. The flow of the lime and gas is carefully regulated so as to maintain an alkalinity approximating very closely to 0.25 per cent until all the lime required has been added. The usual total quantity of milk of lime of 35.7° Brix is from 4 to 5 per cent of the volume of the juice.

Approximately 20 tons of lime-stone and 1.8 tons of gas-coke are used per 1000 tons of cane in producing the lime and carbonic-acid gas. The carbonation is now continued to neutrality to Dupont paper and the juice is heated to 70° C. The injection of the gas is continued one minute after neutrality is reached. The object of this over-carbonation is to prevent particles of lime that have not been converted into the carbonate from rendering the juice alkaline and discoloring it.

The juice is now filter-pressed as in the preceding process. The required filter-cloth area is approximately 1.7 square feet in a frame-press per 1 milling capacity-ton of cane per day.

The filtered juice is concentrated to sirup and, after cooling, is sulphited to an acidity equivalent to 25 to 30 cc. of 100th-normal alkali per 10 cc. of sirup.

16. Double Carbonation Process.—All carbonation methods are based upon the original French process used in treating beet-juices. The double process as applied in cane factories differs from the modern beet method only in the temperature of the operation and in carbonating to neutrality to phenolphthalein paper (Dupont paper).

From 7 to 10 per cent by volume of milk of lime of 35.7° Brix is added to the juice, which is warmed to about 113° F. (45° C.). The first carbonation is then conducted precisely as in the single carbonation method (15) up to the point when the spoon test shows a sharp separation of the precipitate from the juice or a chemical test shows about 0.04 per cent alkalinity. Shortly before this alkalinity is reached the juice is warmed to a temperature of nearly 55° C. and is then filter-pressed. Nothing would be gained by continuing the gassing to a lower alkalinity than 0.04 per cent. With this alkalinity there is no danger of redissolving parts of the precipitates, the juice filters very freely and sufficient lime is left for the second carbonation or saturation.

Lime may or may not be added to the filtered juice from the first carbonation preliminary to the saturation. This juice usually contains sufficient lime except when, through error, the gassing has been pushed too far. The second car-

bonation proceeds very rapidly, without foaming, and is pushed to neutrality as in the preceding processes. The juice is finally heated to 158° F. (70° C.) preparatory to filtration, and before discharging from the tank should be gassed for a few seconds to prevent deleterious action of particles of caustic lime that may have been occluded in the precipitates.

The saturated juice, on account of the condition of the precipitates, is filtered under very low pressure. Gravity filters or shallow frame-presses are usually used for this purpose with a pressure of but 4 to 5 pounds. (*See* 24.) The filter press with gravity pressure is the more economical means of filtering.

The object in conducting the process in two stages and filtering the strongly alkaline juice from the first is the removal of substances that are soluble or slightly so in neutral solution. Among these substances is magnesia, usually largely derived from the lime-stone, the oxalates and possibly other organic salts and substances, such as coloring matters, that are held mechanically by the precipitates.

The precipitates from the second filtration are usually mixed with the juice going to the first filter-presses and are thus subjected to washing with the press-cake.

Sulphitation of the filtered juice from the second carbonation is practiced as in the previous processes and as recommended by Harloff in the following paragraph, and it is then concentrated to sirup. The sirup, after cooling, is usually sulphited to an acidity equivalent to from 15 to 30 cc. of N/100 alkali per 10 cc. of sirup.

17. Harloff's Acid Thin-Juice Process.—Harloff's experience in Java led him to a study of the influence upon the juice, sirup, and consequently the sugar, of various salts, especially the potassium sulphites and carbonates and the corresponding salts of lime and iron. These studies led to a very general practice of sulphiting the raw juice or the carbonated juice to acidity to phenolphthalein in the Java factories. The writer visited many factories in Java in the summer of 1913, and, with very few exceptions all sulphited to acidity. It had long been the custom to sulphite sirup to acidity, but not the juice.

Of most importance, Harloff [1] found that sulphites do not darken clarified juice containing glucose on heating and that carbonates do. This led to the natural conclusion that in so far as may be all the salts should be converted into sulphites, since it is impracticable to remove them. He accomplishes this by sulphiting to neutrality to litmus, which corresponds to slight acidity to phenolphthalein. Further, iron salts, if present in the raw or carbonated juice, are in the ferric state. These salts are reduced to the ferrous state in juices by the sulphurous acid and are colorless and remain so in acid solution. The ferrous salts do not crystallize out with the sugar from acid solution.

Litmus cannot be conveniently used at night or when the light is poor, and therefore, is an uncertain instrument in the hands of a laborer. Harloff recommends the use of the Vivien tube, Fig. 13, which is employed largely in France in beet-sugar work. The tube is filled to the zero mark with N/100 potassium hydroxide containing phenolphthalein, and sulphited juice is added until the red color is discharged. If, for example, the requisite quantity of juice to discharge the color is 10 of the scale on the Vivien tube and a smaller number is obtained, the juice is too acid and the injection of sulphurous acid must be reduced. Check tests should occasionally be made with juice neutralized to litmus in daylight. Obviously a burette control could be used, but this is not quite so easy a manipulation as with the Vivien tube.
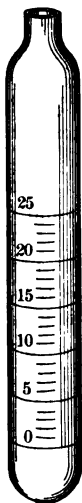
Fig. 13.

Harloff recommends that the juice mixed with the precipitates be not heated to a higher temperature than 90° C. (194° F.) in closed heaters on account of fouling the heating-surfaces. Heating above this temperature should be in open tanks.

It has been the custom for a great many years in Louisiana to work with an acid juice simply because with this condition

[1] W. H. Th. Harloff's "Plantation White Sugar Manufacture," Norman Rodger, London, should be consulted for a very thorough study of carbonation and sulphitation in the cane industry.

the color of the sugar is better, and apparently with no definite idea as to why this is true. Harloff's investigations show very clearly why the sugar is better.

Harloff calls attention to the corrosion of the tubes of the evaporators, on the vapor side, when the juice is left acid to litmus. He also states that the return waters are acid under this condition and damage the tubes of the steam boilers. The boiler-feed water should be rendered slightly alkaline with soda when sulphitation is practiced.

18. Wijnberg's Norit Process.[1]—The juice is defecated as in the ordinary raw-sugar process, except that lime is added to slightly short of neutrality. Ten per cent or more of "norit," figured on the apparent solids in the juice, is added to the decanted juice. The reaction of the juice to litmus must remain acid, and, if not so, phosphoric acid should be added. The juice is heated to boiling-point and filter-pressed. The cake is sweetened off as is usual and is then boiled with a 5 per cent caustic soda solution, filtered and washed, and is finally washed with diluted hydrochloric acid. The norit is then ready for re-use. After several uses, the norit is reburned in a kiln. The sirup from juice treated with norit is filtered with the addition of kieselguhr and is then ready for boiling to white sugar.

Norit is a carbon of very high decolorizing power and is manufactured by a secret process. It not only removes color, but a large part of the gums.

19. Remarks upon White Sugar Processes.—Factories producing plantation white sugar, with few exceptions, make a "near" or "off" white product as compared with the American refiner's standard granulated sugar. In occasional "runs," however, in well-equipped factories, the product is almost or quite indistinguishable from refined sugar.

It is difficult to produce a perfectly uniform quality of sugar in the factory owing largely to the variable purity of the raw material. Judging from conversations with many producers of white sugar, that made by the carbonation processes is of more uniform quality than by the exclusively

[1] Int. Sugar Journ., 1912, 720; 1913, 248 and 404; 1914, 488, all relative to patents.

sulphitation processes. The latter are usually the cheaper processes.

There is a marked rise in the coefficient of purity of the juice in the carbonation process. This rise often exceeds two degrees. It is a true rise and is reflected in an increased yield of sugar. The rise of purity by sulphitation is not so great as by carbonation and de Haan claims that the latter process increases the yield of sugar more than 2 per cent over sulphitation processes and more than justifies the increased cost.

There is considerable difference of opinion as regards the possibility of making as white a product from the very dark-colored canes as from the light yellow and so-called white canes. The effect of the dark color is reduced by increase of lime in the defecation as in the carbonation and Bach processes. It is very probable that the best white sugars are produced from the light-colored canes.

Great attention to detail is essential to successful white-sugar manufacture. A little carelessness in the carbonation or sulphitation and filtration will result in a poor product. Double purging of the sugars in the centrifugals reduces the risk of staining the sugar through the necessarily imperfect removal of the molasses. Thorough cleanliness from start to finish is very essential; not only from the point of view of color, but also of yield of sugar.

SPECIAL APPARATUS USED IN THE SULPHITATION AND CARBON-
ATION PROCESSES.

20. Sulphur Stoves or Ovens and Sulphitors.— These stoves are of two general types: (1) Those employing induced draft and usually used in connection with sulphur-towers or boxes; (2) closed stoves, Fig. 14, into which compressed air is forced and which deliver the sulphurous-acid gas under pressure. These are used with all types of sulphitors.

In the first type the draft is usually induced by a steam-ejector placed on the sulphur-box. Air is drawn into the stove over the burning sulphur and the sulphurous acid produced by the combustion is drawn through the juice falling from shelf to shelf in the box. The surplus air and

gas are ejected at the top of the box. The stove is usually a simple cast-iron box, provided with a suitable door and regulating damper.

The second type of stove, Fig. 14, is used almost exclusively in large plants and in the beet industry. The body of the stove is water-jacketed for cooling. A large pipe, usually 6 to 8 inches in diameter, also water-jacketed, leads about 4 to 6 feet to the gas-main. This pipe serves as a subliming-chamber and catches a large part of the sublimed sulphur. Suitable valves are provided for disconnecting the stove from the main pipe-line so that a stove may be cleaned without interfering with the others in the battery. Air for the combustion of the sulphur should be drawn through a drying-box and then forced into the stove by a compressor.
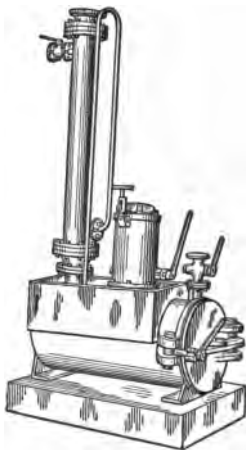
FIG. 14.

It is very essential that the sulphur-stove, no matter what its type, be provided perfectly dry, clean air for the combustion in order to avoid partial oxidation to sulphuric acid. An adaptation of the following arrangement for closed stoves should be used with the induced draft-type.

The drier is preferably a cast iron-box provided with a tight-fitting door and trays for holding layers of quick-lime. The air enters the box at the bottom and passes over the lime on its way to the compressor. It is advisable to place a settling-chamber between the drier and the air-compressor to catch the lime-dust. A drier about $3' \times 3' \times 4'$ is usually large enough for a stove of 8 square feet fire area. Two stoves of this size are sufficient for a factory consuming about 750 lbs. of sulphur per day. A reserve stove should also be provided.

A filter-box filled with coke is sometimes used to remove dust and sublimed sulphur from the gas.

The usual Louisiana sulphitor is described in connection with the induced-draft stove. Sulphitation tanks are of many forms, but the usual one is a moderately deep iron-tank provided with a cover and chimney to the outer air, suitable test-cocks, valves, and a perforated pipe for distributing the sulphurous-acid gas. The pipes and tanks should be arranged to facilitate cleaning at frequent intervals. The bottom is preferably conical. Perforated pipes for steam-jets to break down foam should be provided in sirup sulphitors. Where the tank is used to saturate large quantities of lime, as in Bach's process, intermittent work is advisable, and at least three tanks should be installed, otherwise a single continuous sulphitation should be used. Two tanks may be used in this method, though one very deep one with more careful manipulation will answer. The juice enters the first tank at the bottom and is sulphited to approximately the desired test. It overflows and enters the second tank at the bottom and is sulphited to the required acidity. From the second tank the juice flows through juice-heaters and filters to the charge-tanks of the evaporator.

21. Carbonation-tanks.—The carbonation-tanks are of iron and should be more than 20 feet in depth for the first carbonation or otherwise should be provided with perforated pipes for steam, carbonic acid or air-jets to break down foam. The tanks should have sufficient steam-coil capacity to heat the juice quickly. The carbonic-acid and juice-connections should be large to provide for rapid work. A first carbonation should require about ten minutes and a second about three to five minutes for the gassing.

Formerly the gas was led into the juice through perforated pipes. Such pipes always give trouble through incrustations of lime. In more recent practice the gas enters through a large pipe in the conical bottom of the tank and is deflected at intervals by baffle-plates or other device, so arranged as to insure thorough distribution of the carbonic acid. There are many methods of arranging the pipes to reduce the scaling and facilitate cleaning them.

Continuous carbonation is advisable for the second stage of the process. The quantity of lime to be saturated is very small and with a suitable device the outflowing juice is

readily carbonated to the desired point. There are several continuous carbonators on the market designed for beet work. Descriptions of them will be found in many works on beet-sugar.

If intermittent second carbonation is practiced, the tanks may be comparatively shallow, as there is little foaming.

22. Lime-kilns.—The carbonic acid is obtained from lime-stone calcined by coke-fires in a special continuous kiln. This kiln, as also all other carbonation and sulphitation machinery are the identical devices that are used in beet-sugar manufacture.

The kiln proper is 25 to 30 feet high and is the frustum of a cone of narrow angle with the small end upward. A mixture of lime-stone and coke is fed into the kiln at the top through a conical self-closing door. Three distinct zones are maintained in the kiln, viz.: (1) at the top, the fresh stone and unignited coke; (2) at the middle is the combustion and dissociation zone; (3) below the combustion-zone is that in which the resultant lime is cooled and drawn off.

Kilns are usually built of the Belgian type in which the body is supported upon four short columns, leaving the bottom open and free for the discharge of lime. The columns stand upon a concrete platform upon which the lime rests. Stone is piled upon this platform to support the kindling and mixture of stone and coke, when the kiln is put into commission. As the firing progresses and the lime is produced this stone is removed from time to time and finally its place is taken by quick-lime. The kiln is provided with numerous openings, having tight-fitting plates or doors, for use in watching the progress of the firing and for breaking down "scaffolds."

The draft is induced by the carbonic-acid pump, which is located conveniently near the carbonation tanks. A pipe leads the gas through a washer and scrubber and thence to the pump which discharges it into the carbonation-tanks. The gas is thoroughly washed with water.

The kiln must have but one inlet for air, and that where the lime is discharged. The quantity of air drawn in, and, therefore, the combustion, is regulated by the speed of the carbonic-acid pump. It is evident that this pump must be kept in thorough order and must work with great regularity,

since the success of the carbonation depends upon it. The zone of dissociation must be maintained in its proper place. The essential conditions are the delivery of rich gas containing above 30 per cent of carbonic acid and properly burned lime..

The gas should be frequently tested as described in **275, 276.** The quality of the coke and stone [1] must be controlled. The following brief summary of kiln conditions will assist in the interpretation of analyses:

(1) The gas contains a large excess of oxygen, little carbonic oxide, and a low percentage of carbonic acid: Leakage is indicated at a point between the gas-pump and the kiln. If the combustion zone is white hot the gas-pump is running too fast or the coke is too coarse. The draw of lime should be increased.

(2) The gas contains too little carbonic acid and neither carbonic oxide nor oxygen is excessive: Smaller quantities of lime should be drawn and at longer intervals. The mixture of stone and coke should be investigated, as the proportion of the latter may be too large.

(3) The richness of the gas in carbonic acid is fluctuating: The pump may be running too slowly and irregularly.

(4) The gas contains an excess of carbonic oxide and normal quantity of oxygen: The combustion of the coke is incomplete and carbonic acid is converted into monoxide on account of deficiency of oxygen; other conditions being normal, the coke is too coarse and the pump is running too fast.

(5) The gas contains both oxygen and carbonic oxide in excess: The circulation of the gas is slow and the sampler is drawing some air.

The American beet-sugar factories usually use high-grade metallurgical coke in their kilns. The high cost of such coke has forced the Java factories to substitute the cheaper gas-coke and oil-still residuum. The residuum is used in the ratio of 1 to 12 of stone by the weight. Coke is used in ratio of 1 to 9.5–11 of stone.

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[1] See " Hand Book for Chemists of Beet Sugar Houses," G. L. Spencer, p. 211, for analyses of lime-stones and a discussion of their qualities. Also analysis of lime-stone, this work, p. 386.

FILTRATION PROCESSES AND MACHINERY

23. Filtration.—In the usual processes of cane-sugar manufacture the entire clarified juice is not filter-pressed, but only that portion contained in the scums and precipitates from the defecation. With the carbonation process all of the juice may be readily filtered through ordinary presses. The juice clarified by the defecation process contains fine flocculent matter which soon obstructs the pores of the cloth. Several processes, depending upon the addition of sawdust, lignite, charcoal, etc., to the clarified juice preparatory to filtration, have been devised, but none has been practically successful. In the Bach sulphitation process, both the juice and sirup may be filter-pressed. The precipitated calcium sulphite supplies a filtering medium as does the carbonate in the carbonation processes.

In recent years, mechanical filters of many types, using sand, cloth, or other filtering media have been used with varying success. Sand filters apparently give good results.

Bone-black filters were formerly used in making plantation white sugars, but these have been displaced by the sulphurous-acid processes.

The scums and juice tank-bottoms may be easily filter-pressed. It is advisable to thoroughly heat this material in steam "blowups," settle the mud, and decant the clean juice preparatory to filtration. There is a gain both in sugar and facility of filtration by this treatment. There is an additional gain of sugar by adding water to the residual mud and again heating and settling it, and decanting the thin juice. The mud filter-presses more readily when alkaline, therefore lime should usually be added to it.

24. Mechanical Cloth Filters.—Cloth filters are of two kinds, viz.: (1) Bag filters, in which the filtration is from the inside of the bag outward; (2) mechanical or gravity filters, in which the filtration is from the outside toward the inside of the bag.

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Bag filters are used largely by refineries and but little in sugar-factories. Each filtering element consists of an outer and an inner bag. The mud collects inside the bag, and in the case of sugar-factory work contains about 80 per cent or more of juice. Unless this mud is washed in the bag it is evident that there is a large loss of sugar with these filters.

Mechanical filters are not very satisfactory in the filtration of juice purified by the defecation process. The expense for cloth and labor is very large and the capacity of the filter is small. Bag-filters give better results for this purpose. The mechanical filter may be used for filtering juice from the second carbonation, but presses using shallow frames working under low pressure are more economical.

The mechanical filter consists of a large number of rectangular bags suspended in a closed iron box. Each bag or pocket has an independent discharge-pipe communicating with the inside of it. A metal distender prevents the bags from collapsing. The clarified juice flows into the filter by gravity, under a low head, fills the box, and filters into the bags. The mud collects on the outside of the bags and from time to time falls off. The pressure is so low that the mud is not impacted upon the cloth. When the cloths become foul, the flow of juice is shut off and the mud is sent to the filter-presses.

25. Sand Filters.—Several types of sand filters for juice and sirup are in use. As the name of the filter implies, the filtering medium is fine, sharp sand. Pulverized coke may also be used. The filtering material must be of grains of uniform size, otherwise the filter will soon clog.

When the filtering medium is clogged with mud the juice it contains is displaced with water and the sand is then thoroughly washed with hot water under pump-pressure or otherwise, according to the type of the filter. After washing the filter is again ready for service.

These filters have been used with moderate success in the cane-industry. Many of those installed a few years ago have been converted into the excelsior filters described below.

26. Excelsior Filters, Bagasse Filters, etc.—*Excelsior Filters.*—The excelsior filter was devised in the Hawaiian

Islands for filtering clarified juice. A small tank, about 2.5 to 3 feet deep and of convenient dimensions for manipulating the filtering medium, is fitted with a false bottom about 2 inches above its bottom. A pipe-line for bringing clarified juice to the filter is connected with it at the center of the tank's bottom and over this inlet is placed a small baffle-plate to break the force of the current and distribute the juice. An overflow-pipe is connected near the upper edge of the tank to lead the filtered juice to the charge-tanks of the evaporators.

The filter is prepared for work by packing it with the ordinary excelsior that is used in shipping merchandise. A wire screen is placed on top of the excelsior to prevent it from floating and to retain particles of the material that might be carried along with the juice. A filter capacity of approximately 150 cubic feet of excelsior is necessary per 1000 tons of cane.

These filters will not materially improve cloudy juice caused by defective liming and defecation. If the juice has been properly limed and heated, but carries suspended matter and cane-fiber, the filters will greatly improve it.

An advantage of the excelsior filter is its freedom from fermentation or serious clogging with precipitates. The excelsior may be washed in the filter or in an ordinary washing-machine and used over and over again.

Bagasse Filters.—These filters are constructed in precisely the same way as the excelsior filters except that fine bagasse is the filtering medium. When the filtration becomes sluggish the bagasse is removed from the filter and put upon the mill-carrier for regrinding.

This material has a great tendency to ferment and thus contaminate the juices during filtration. For this reason it is a much less desirable filtering medium than excelsior.

Fiber Filters, etc.—Various fibers are used to a limited extent in a way similar to excelsior. Thin sheets of paper-pulp have found a small application in sirup-filters. Granulated cork, asbestos and many other materials have been used and with little success. Cane-juice and sirup by the defecation process cannot be readily filtered, except after treatment by some process that will largely remove the gums.

In a very old French process, alcohol was used as a precipitant in sorghum-juice. Filtration followed without difficulty. The U. S. Department of Agriculture [1] modified this process in adding an equal volume of strong alcohol to sorghum-sirup of about 55° Brix. A very heavy precipitate consisting partly of gums was thrown down and was very easily removed by filter-pressing. The alcohol was recovered by distillation and the sugar was crystallized as is customary.

Centrifugal Separators.—Several forms of centrifugal separators have been brought out by inventors from time to time. In these the machine differs from the ordinary centrifugal in having no perforations in the basket. The defecated juice or even juice without previous removal of the mud (cachaza) is run into the machine near the bottom of the basket. The mud is thrown to the wall of the basket by the centrifugal force and the clean juice flows over the rim.

The cost of the plant and the expense for power, loss of heat, oil, etc., are possibly the reasons for the small extension of this process. If the defecation is good and the separation of the precipitates therefore sharp, the centrifugals will deliver very clean clarified juice.

27. Filter-presses.—Filter-presses are so generally used in the sugar industry that full description of them is unnecessary. Briefly, a filter-press consists of a number of iron plates and frames or recessed plates over which filtering cloths are placed. The frames and plates are supported on a heavy framework and are clamped together by a powerful jack-screw. The cloth itself makes the joints between the frames and plates.

There are two general types of presses, the center-feed and side-feed or frame presses.

The center-feed presses are made up of heavy recessed plates, with a round opening in each and a corresponding hole in the cloth to form the inlet channel. The cloth is clamped to the plate at each of these openings.

There is no hole in the cloth in the frame-press. A lug projects from each frame and plate and in each there is an opening to form the mud-channel. Rubber rings or cloth "stockings" form the joints between the lugs.

[1] See the reports of the Bureau of Chemistry.

When a press is in use the mud collects in the frames or recessed plates and the filtered juice runs off through suitable openings.

Filter-presses are usually arranged so that the press-cake may be washed or the juice it contains be displaced with water. In displacing the juice the cocks are closed on the water-plates and water is forced through the cake, driving the juice ahead of it. This is feasible only in defecation factories having very large filter-press capacity, as the displacement is exceedingly slow. This method is applicable in the carbonation and certain of the sulphitation processes. In order to economize wash-water and consequently fuel for evaporating, the last runnings of a previous press are often used in beginning the washing of the cake.

Double filter-pressing is a very efficient method of exhausting the press-cake of sugar in the defecation and other processes. The first pressing is conducted as is usual. The first press-cake is conveyed to a machine for breaking it and then it is beaten to a cream with water. This cream is next heated to boiling and is then pumped into a second set of filter-presses. The filtrate from these presses may be used in diluting mud (cachaza) preparatory to the first pressing. This method requires a filter-press plant of sufficient capacity to devote about one-third of the presses to the second filtration. The sucrose content of the press-cake may readily be reduced below one-half per cent without excessive use of water.

A pressure of 40 lbs. to the square inch is sufficient for very good press-work. With heavier pressure there is risk of breaking the presses and liability of forming a coating of almost impervious material upon the cloths.

It is the usual practice in making white-sugar to filter-press the mud without liming it. It is often advisable to use a moderate quantity of lime, and if necessary reclarify the filtered juice, mixing it with clarified juice, or acidulating it with phosphoric acid.

Worthington Filter-press.—A recent form of filter-press is the Worthington, in which the mud (cachaza) is run into bags to drain off part of the juice and the residual mud is pressed between a pair of heavy jaws. A working

capacity of 400 gallons of cachaza per press per hour is claimed.

Kelly Filter-press. —Sweetland Self-dumping Filter.— These filters are a development of the mechanical type of filters, described in **24**, in so far as the filtration is from the outside to the inside of a bag.

The Kelly, Fig. 15, was the first filter of this type to be used in cane-sugar manufacture. Filter-bags are placed over frames suspended upon suitable pipe-rack and are enclosed in an inclined cylinder. Each bag communicates with a filtered juice-canal. Muddy juice (cachaza) is ad-
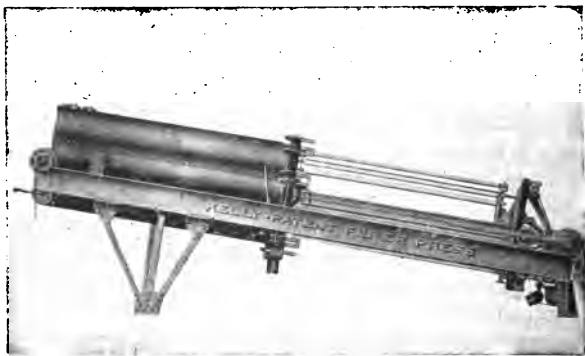
Fig. 15.

mitted to the cylinder under considerable pressure. The mud attaches itself to the cloths and the juice flows through the latter into the pipes leading to the canal. The operation is stopped from time to time and the end door of the cylindrical body is opened for the removal of the rack and the discharge of the mud. The mud or press-cake may be washed to low sucrose content in the press. The cloths require changing at very infrequent intervals.

The Sweetland press, Fig. 16, or "clam-shell" type of press takes its name from its two parts opening and closing

after the manner of the clam-shell steam-shovel bucket.
The body of the filter comprises 2 semi-cylindrical members
hinged together, with suitable gaskets, to form a water-tight
cylinder when closed. The filter leaves are composed of
crimped-wire screens, each provided with an outlet nipple
for the filtrate. Filter-cloth is fastened over these screens
and these latter are so arranged that they may be clamped
tightly in place in the filter body with the outlet-nipples in
connection with the delivery fittings outside the filter.
Variable spacing is provided for the leaves to suit different
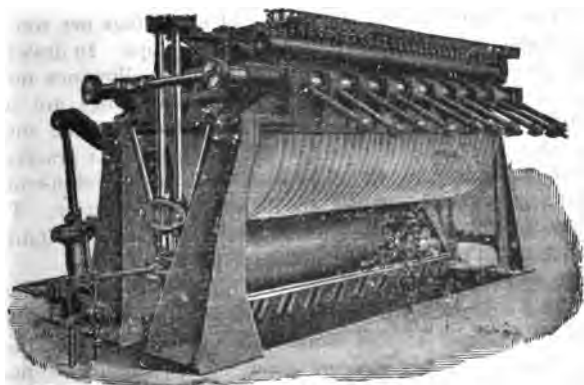
Fig. 16.

filtration conditions. Each leaf has separate delivery,
shut-off cock, glass delivery-tube, etc. The opening and
closing of the press is easily and quickly accomplished, the
large size of presses using hydraulic power. Several presses
may be operated at the same time from one hydraulic valve.

The liquid is forced into the filter. It displaces the air
and submerges the leaves. The mud collects upon the
cloths and the liquid passes through them to the outlets.
This process continues until adjacent filter-cakes are but
slightly separated. The cachaza-valve is then closed and
the wash-water valve is opened. The water displaces
the juice in the cake and removes a large part of the sugar.

After washing, the cakes are partially dried by compressed air, if so desired, and the lower half of the body is swung open and they are discharged. Steam or compressed air may be used inside the leaves to loosen the cakes from the cloths. A coating of kieselguhr on the cloths facilitates the discharge of the cakes. This is applied in water suspension before filtration begins.

28. Disposal of the Skimmings in Diffusion-work. —The skimmings from diffusion-juices are sometimes difficult to filter-press. A simple method of their disposal consists in returning them to the diffusion-battery. A measured volume, approximately 10 gallons of skimmings per ton of cane, should be added to each cell of cane-chips. In drawing the juice from cells containing skimmings, allowance must be made for their volume. If the skimmings are not settled, considerably more than 10 gallons per ton must be added to each cell of chips. If this method is practised settling-tanks may be dispensed with in diffusion-work. The sooner the skimmings are disposed of the better. The skimmings can easily be filter-pressed if rendered slightly alkaline and heated to the boiling-point.

Many chemists and sugar-makers question the advisability of returning the skimmings to the diffusion-battery. The objection urged is that under the influence of the long-continued high temperature some of the impurities may be redissolved and may not be reprecipitated in the defecation. In the early days of diffusion-work with cane, difficulty was sometimes experienced in filter-pressing the skimmings; this led to the adoption in some houses of the plan of returning them to the battery. This method is a very attractive one, as it does away with the costly filter-presses and a heavy expense-item for cloths and labor. Moreover, the loss of 1½ to 2 lbs. of sugar per ton of cane contained in the press-cake may be almost entirely avoided. To what extent the advantages of this process are offset by the possible and even probable return of impurities to the juice has not been estimated.

29. Reclarification of Filter-press Juice.—Many sugar-makers return the filtrate from the presses to the defecators; others clarify and resettle this filtrate separately

and then mix it with the clarified juice; still others pump the filtrate directly to the charge-tanks of the evaporators This last is an objectionable practice, no matter how clean the juice may appear to be, especially if lime has been added to the mud (cachaza) preparatory to filtering. Such filtrates greatly increase the scaling of the tubes of the evaporator.

CHEMICAL REAGENTS USED IN PURIFYING THE JUICE.[1]

30. Lime.—The most effective agent of moderate cost that has been found for the treatment of the juice is lime. There are several methods of preparing this substance for use in the defecation of cane-juice as follows: (1) Quicklime is ground to a fine powder which must be slaked with water before liming the juice. This method is used in Cuba. (2) Dry slaked lime is prepared by sprinkling water on heaps of lime. The sifted powder is mixed with juice preparatory to use in the defecation. This form of lime is also used in Cuba. (3) A milk of lime of 15° Baumé is prepared from quicklime and is pumped to the defecators through pipe-lines, in which it is kept constantly circulating. This method is used very generally throughout both the cane and beet-sugar industries. (4) The lime is slaked in large tanks and then allowed to settle and form a heavy paste. The supernatant water is drawn off. The paste is weighed for use in the defecators.

The preparation of the lime is of great importance, especially in the manufacture of white sugar. Essential conditions in properly slaking lime are that full time be allowed for the reaction and that too much water be not added, thus reducing the temperature. The slaking-tanks should be large so as to retain the heat of the reaction and promote the slaking.

When the factories of Louisiana were very small, it was the custom to slake the lime in advance of the grinding season. The milk was reduced, after slaking, to a low density with water and then passed through fine screens

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[1] A list of several hundred substances and combinations that have been proposed for use in sugar manufacture, is given on page 532.

into a second tank and so on until all the containers were filled. After allowing a few days for the hydrated lime to settle out, the supernatant liquid was drawn off and fresh portions of the strained milk were added to the paste already in the tank. The alternate drainage and settling were repeated until all the tanks were filled with the heavy lime-paste. The author has frequently noted indications of further slaking even two or three weeks after the tanks had been filled. This description is given to emphasize the importance of the time element.

The lime used in the purification of the juice should be very pure. The magnesia and soluble silicates of the lime used in the defecation processes form scale in the evaporators. However, mention is made farther on of the satisfactory use of lime containing large quantities of magnesia.

The quality of the lime-stone used in the carbonation process is of great importance. Certain stones rich in silica tend to "scaffold" in the kiln, and others have hydraulic properties, resulting in an almost impervious filter-cake. Examples of lime-stones and comments on their characteristics are given in the author's "Handbook for Chemists of Beet-sugar Houses," p. 211.

Lime from coral beach-sand is used to some extent in the Hawaiian factories. The following analysis [1] of lime from this source shows high magnesia content: Silica 0.18 per cent; lime 91.7 per cent; magnesia 4.15 per cent. Analyses made for the author of two Cuban coral sands (dry) gave a magnesia carbonate content of 6.6 and 4.5 per cent. The first of these Cuban sands would produce lime containing 92.5 per cent calcium oxide, 6.0 per-cent magnesium oxide and 1.5 per cent silica, etc.

The following information relative to coral sand is from the Paia factory, Island of Maui, H. T. [2]: "Coral sand is burned in rotary kilns with temperature control. Damp sand is preferred, since the temperature at which dissociation of carbon dioxide takes place is slightly lessened in the presence of steam generated from the moisture."

"Coral sand contains considerable magnesia which is

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[1] Spec. Report, July, 1913, Expt. Sta. Haw. Sugar Planters' Ass'n.

[2] Planters' Monthly (Hawaiian), Nov., 1909, 444.

usually presumed to be objectionable in the defecation owing to its depositing upon the heating-surfaces. Further, a portion of the magnesia remaining in the molasses would increase the molasses output with consequent loss of sucrose. The experience of the Maui Agricultural Co., Paia factory, showed a large elimination of the magnesia in the press-cake. The defecation was good, the yield of sugar satisfactory and the output of molasses was small. The lime contained 5.45 per cent of magnesia." The writer visited Paia in 1913 and saw coral lime in use in the defecation process. The alkaline filtration in the double carbonation process eliminates the magnesia from the juice.

30a. Sulphurous Acid.—The production is described in the white-sugar chapter, page 58. This reagent is little used in raw sugar manufacture except in Louisiana.

Aside from its bleaching effects the sulphurous acid produces a heavy precipitate with the lime which assists mechanically in the clarification. It also breaks up some of the lime salts and thus reduces the viscosity of the sirup and massecuites. Sulphured sirups and massecuites boil much more freely in the vacuum-pan than those made without this reagent.

31. Carbonate of Soda, Caustic Soda.—Juices which have begun to ferment are better neutralized with soda, rather than with lime, as the latter produces soluble salts that are very objectionable. The soda salts are also useful in neutralizing molasses. The carbonate apparently has a beneficial effect when taken into the pan in boiling stringsugars.

Carbonate of soda is an incomplete precipitant of lime from its salts in sugar solutions. In a series of experiments de Grobert [1] found that the addition of carbonate of soda to a sirup in the proportion of its equivalent of lime precipitated about 52 per cent of the lime. The addition of two equivalents more of soda precipitated 81 per cent of the lime. A part of the soda remained in a free state and the remainder was neutralized by the organic non-sugar. M. de Grobert states that if carbonate of soda is used in juices, sirups, etc.

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[1] Eighth Cong. App. Chem., 8, 21.

it should be the theoretical quantity required to combine with the lime.

L. R. Cook [1] cites an experience in pan-boiling in beet-sugar work when an excessive amount of lime salts in the low-grade material prevented the pan from boiling. Cotton-seed oil was injected into the massecuite and improved the conditions. The oil was then saponified with caustic soda. This immediately further improved the conditions and the pan boiled freely.

A viscous or very heavy massecuite that is difficult to pump usually yields readily after the addition of carbonate of soda. Such massecuites are more easily purged in the centrifugals after the soda treatment.

S. S. Peck [2] advises the addition of sodium carbonate to a raw juice that contains excessive quantities of sulphuric acid which tends to form calcium sulphate scales in the heaters and evaporators. The sodium carbonate decreases the amount of insoluble ash, phosphoric acid and lime in the filtered juice; it partially removes magnesia; it increases the amount of material removed by the filter-presses and effects a slight increase in the proportion of organic impurities removed from the juice. Not enough lime will be left in juices of high sulphuric acid content to form a serious sulphate scale. The use of carbonate of soda materially increases the cost of the defecation.

32. Phosphoric Acid. — Phosphoric acid and superphosphate of lime, under various trade-names, are used to a large extent in Louisiana in the clarification of the juice, as a sugar-wash at the centrifugals, and in the preparation of molasses for reboiling.

In the clarification, the phosphoric acid or the phosphate is added in small excess to the slightly over-limed clarified juice. The juice is then boiled and brushed, and run into the settling-tanks.

33. Various Chemicals Used in the Defecation of the Juice. — A very large number of substances have been proposed for use in purifying the juice and a very few have to a very limited extent been practically applied in manu-

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[1] *Op. cit.*, **27**, 61.

[2] Bul. 33, Expt. Sta. Haw. Planters' Ass'n.

facture. Among these substances are barytes, hyposul-
phurous acid (made by the reduction of sulphurous acid
with zinc or tin dust), hydrosulphites of sodium and of
calcium, clay, alumina, etc.

Hyposulphurous acid is used in bleaching molasses, also
tin salt, or muriate of tin. The last named is also used in
centrifugal washes for yellow sugars.

Kieselguhr is used as a filtering medium. The addition
of this material to juice or sirup greatly facilitates filtration.

EVAPORATION OF THE JUICE.[1]

34. Multiple-effect Evaporation.—In the old proc-
esses of sugar-manufacture, the juice was evaporated to a
sirup and the sirup to the point of crystallization, in open
kettles over a fire or in pans in which the liquor was boiled
by live steam-coils. These processes have nearly disappeared
and are only used in very small factories and by but few of
these except in places where the price of sugar or molasses
is very high, or where local conditions permit.

The evaporation is in multiple effect in the modern factory,
the steam being made to do duty two or more times, according
to the type of the evaporator. The evaporation is con-
ducted in various forms of vacuum apparatus, of which the
so-called "standard" triple-effect is the most generally used.
In this form of evaporator, a description of which will answer
the purposes of this book, the liquor is boiled in a deep layer,
from 3 to 4 feet in depth, whereas in shallow and film evapora-
tors the depth varies from a few inches to but a thin film,
according to the type of the evaporator.

The standard type of the evaporator, in triple-effect, con-
sists of three vertical cylindrical vessels, termed "pans" or
"effects"; the lower part of each is provided with a steam-
drum fitted with copper or brass tubes, through which the
juice circulates and which are surrounded by steam. The
steam-drum is termed the "calandria." In the center of
the calandria is a large tube which carries the juice back
to the lower part of the pans as it boils up through the
tubes. This large tube is called the "down-take."

The space above the calandria, the vapor-space, is con-
nected by means of a large vapor-pipe with the steam-space
of the second pan, and the vapor-space of the second pan with
the calandria of the third. The vapor-space of the third
pan is connected by a large pipe with the condenser and

[1] *See* pp. 350-381, "Evaporating and Juice Heating," by Prof. W.
H. P. Creighton.

vacuum-pump. The juice in the first pan is boiled by the exhaust steam from the various pumps and engines and its water of condensation flows through a trap to the boiler-feed water-tank.

The vapor generated in the first pan is used to boil the juice in the second, and that generated in the second to boil the sirup in the third pan. The juice is fed into the first pan and circulates from pan to pan and finally reaches the third, the thin juice being admitted as fast as the evaporation of the water and the removal of finished sirup permits. A vacuum is produced in the third pan by the pump and condenser and in the first and second pans by the condensation of the vapors in the calandrias of the second and third pans. The vacuum in each pan depends somewhat upon the working conditions, but is usually about 5 to 7 inches of mercury in the first, 14 to 17 in the second, and 26 to 28 in the third pan. By reason of the differences in the vacuum, the juice travels from pan to pan and the vapors produced in the evaporation in the first pan are hot enough to boil the liquor in the second, and those in the second to boil the sirup in the third pan. The condensation water of the second pan is either drawn into the calandria of the third pan, or is directly pumped to the boiler-feed tanks, and that of the third pan is also removed by a pump.

These pumps are usually termed "sweet-water pumps." The sirup is removed from the third pan continuously by means of a pump, the workman regulating its density by the steam-pressure and the quantity of juice in the first pan, and the rate of pumping the liquor from the third pan. Valves are provided on the pipes connecting the pans to regulate the flow of the liquor.

The procedure described is sometimes somewhat modified by the use of Chapman's circulating-pipes. These pipes are like inverted syphons connecting the liquor-spaces and are of such length that the vacuum in the pans is not sufficient to empty them. They are arranged to maintain a constant level of liquor in the pans without the use of other regulating-valves than those for the juice and steam in the first pan. These pipes cause the liquor to circulate very rapidly through the tubes of the calandria. In operating the

apparatus the workman needs only to regulate the inflow of juice and steam-pressure on the first pan.   It is perhaps needless to state that a very uniform vacuum in the third pan is requisite to satisfactory work with these circulators.

Owing to the rapidity of the evaporation in multiple-effects there is more or less entrainment of juice with the vapors. This juice is recovered by leading the vapors against baffle-plates, usually in a greatly enlarged section of the vapor-pipe. The enlargement of the pipe reduces the rate of the travel of the vapors and permits the deposition of the entrained juice.   This device is called a "save-all."

Multiple-effect evaporators are constructed of two pans called a double-effect, three pans a triple-effect, four pans a quadruple-effect, etc.   The principle upon which all types of this apparatus are based is the same for all and is that outlined in the description of the standard triple-effect. With higher combinations than the triple-effect, the first pan is worked under a pressure within it, instead of a vacuum, and is called the "pressure-pan."

The calandrias of multiple effects are provided with pipes for the removal of the incondensible gases.   A careful supervision of the removal of these gases is necessary, not only because they reduce the efficiency of the heating-surfaces, but, further, they frequently destroy them. The gases contain ammonia derived largely from the decomposition of the amids of the juice, and partly from other nitrogenous constituents. The ammonia should be removed, since· it attacks the upper ends of the copper tubes in the steam-space and ruins them.

It is the practice in the beet-sugar industry and very largely in the cane-factories of Java to utilize a part of the vapor generated in the first vessel of the multiple-effect and, with quadruple-effects, also a part of that from the second vessel in juice-heating.   Vapor is also sometimes supplied in boiling a calandria vacuum-pan and in converting a triple-effect into a quadruple effect.   When the first vessel is "robbed," or "extra steam" is taken from it, larger heating surface is provided in its calandria than in those of the other vessels.   Frequently a pre-evaporator, to increase evaporative capacity and supply vapor for juice heating, etc., is used in connection with the multiple-effect.

The heating-surface of the first effect is sometimes double the requirements of the evaporator so as to supply the extra vapor. The juice heaters in this method of heating are usually of the closed return-tube type. This use of the vapors extends double-effect heating to the juices and, in some instances, even to a part of the massecuites.

Preheaters (Pauly-Greiner) are very little used in the cane-industry, though their use in beet-sugar factories is extensive. This may be due to the large amount of exhaust-steam usually available in cane-factories or to fear of destroying sugar at the high temperature that is necessary. Noël Deerr [1] made a study of the effect of high temperatures upon cane-sugar in solution and among other conclusions he arrived at the following: (1) "The system obtaining in cane-juices is a very complex one, consisting of very variable amounts of salts of both strong and weak acids, and of free alkali. Hence a temperature that may be safe with one juice may cause serious inversion with another. With conditions usually prevailing in local factories (Hawaiian Islands), juices should suffer a half hour's heating at 120° C. (248° F.) with no detectable loss of sugar. It would be conservative to adopt this temperature as the highest to which cane-juice should be subjected during evaporation, though under a careful system of control and observation a temperature of 125° C. (257° F.), or even 130° C. (266° F.) for shorter periods, might be permissible." (2) "The sterilization of cane-sugar products is possible since it occurs almost instantaneously at 125° C." (3) "The use of high-temperature evaporation and the preheater system of evaporation and also the sterilization of all cane-sugar house products is possible under a rational control."

After the concentration of the juice to a sirup in the multiple-effect evaporators, it is pumped to combined settling- and storage-tanks. A considerable quantity of impurities that were soluble in the thin juice are insoluble in the sirup. A part of these impurities deposit themselves upon the heating-surfaces of the evaporator, forming a hard scale. Those which remain in suspension are removed by

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[1] Bul. 36, Expt. Sta. Hawaiian Sugar Planters' Ass'n.

settling and decantation in the tanks mentioned above. The sediment that collects in these tanks is very rich in sugar. This material cannot be readily filter-pressed, therefore it is usually pumped to the defecators or clarifiers, to be diluted with juice and the precipitate removed by decantation.

Instead of pumping the sirup directly to the settling-tanks, it is often first boiled and skimmed, i.e., clarified. This is probably beneficial in the manufacture of white sugar, but at the expense of sucrose, through inversion. The glucose-ratio of the sirup rapidly increases during the clarification, and the scum and foam that rise to the surface have approximately the same coefficient of purity as the sirup from which they are derived.

It is probable that better results, so far as the yield of sugar is concerned, would be realized by rapidly heating the sirup to its boiling-point.

The scale which forms on the tubes of the evaporators must be removed at frequent intervals as it is a very poor conductor of heat. Its composition varies somewhat with that of the cane and in some localities forms very much faster than in others. The tubes of the first pan, which always contains thin juice, scale little compared with those of the other pans. The third pan of a triple-effect contains the thickest and most obstinate scale.

The following analyses of the scales indicate their composition in the different pans of a quadruple effect:[1]

	1st Pan, Per Cent.	2d Pan, Per Cent.	3d Pan, Per Cent.	4th Pan, Per Cent.
Phosphate of lime	57.85	56.98	15.02	7.49
Sulphate of lime	2.02	1.92	0.54	1.65
Carbonate of lime	3.25	4.68	19.55	9.93
Silicate of lime	7.86	13.31	0.71	7.02
Oxalate of lime	.....	.....	11.32	11.27
Iron oxide	2.03	1.53	2.31	2.58
Silica	7.79	7.43	39.26	54.34
Combustible matter	20.37	13.41	11.04	5.08

The tubes may be cleaned by moistening the scale with water and scraping the surfaces. This is a very laborious and tedious method, therefore the following is usually used, and applies also in cleaning the coils of the vacuum-pans.

[1] Prinsen-Geerligs, *Kobus Archief*, 1900, 694.

The pans are filled to above the level of the tubes with a
caustic soda solution containing from one to two pounds
of the soda per cubic foot of solution. This soda solution
is boiled during several hours and is then run from the pans
into an iron or lead-lined store-tank. The pans are washed
with water and then boiled with dilute muriatic acid, which
is afterwards run into the sewer. The acid should be strong
enough to be very acid to the taste. This treatment if
repeated at intervals of about a week will usually keep the
heating-surfaces in good condition. At the end of the
manufacturing season it is usually necessary to give the
tubes a thorough scraping.

The alkali solution may be used repeatedly, adding caustic
soda from time to time as it becomes weakened. The soda
solution is always boiled under atmospheric pressure in
cleaning evaporators and pans.

PRESERVATION OF THE JUICE AND SIRUP DUR-
ING TEMPORARY SUSPENSION OF MANU-
FACTURE.

35. Preservation of the Juice and Sirup with Formaldehyde.—It may be necessary in the event of the breakage of the machinery or delay from other causes to store juice and sirup several hours, or even days. Formaldehyde is a very effective preservative for this purpose. Sirup will usually keep sweet, under tropical conditions, from 36 to 48 hours without the use of a preservative, provided that it is of fully 54.3° Brix (30° Bé.) density and is stored in clean tanks, not in the vicinity of fermenting sugar solutions. Juice will keep sweet but a very short time without a preservative. The method of manufacture influences the keeping qualities of juices and sirup, those treated by the sulphur processes remaining sweet much longer than others prepared with lime only.

Clarified juice, made by the sulphur process, may be stored in clean tanks for thirty-six hours and probably longer by the addition of 3 cubic centimeters of a 40-per cent solution of formaldehyde per cubic foot of juice. Juice clarified by the ordinary process requires considerably more than this quantity of formaldehyde, usually from 6 to 8 cubic centimeters.

Juice may be left in clean defecators and settling-tanks about twelve hours with but little alteration. That there is a change, however, is evident from its increasing acid reaction. The author preserved 30° Baumé sirup during a period of seven days by the addition of 6 cubic centimeters of 40-per cent formaldehyde solution per cubic foot. Possibly less formaldehyde would have answered, but it was not deemed advisable to incur risk. The capacity of the storage-tanks was 5000 gallons each.

Juice may be preserved twenty-four hours in the defecators, without removing the scum or mud, by the use of

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formaldehyde. The measured quantity of the preservative should be mixed with the juice immediately on starting to fill the defecator.

The use of formaldehyde in preserving juices held in Deming's closed separators is not entirely satisfactory. The juice always tends to decompose after standing a short time. This may possibly be due to difficulty in thoroughly mixing the formaldehyde with the juice. The formaldehyde is usually added in the pump-tank, from which it is pumped through the heaters and eliminator to the separators. The decomposition may also be due to organisms that lodge upon the walls of the tank and are not killed by the heat. (*See* also **11**.)

The writer's experiments indicated a slight deterioration of juice, even in the presence of formaldehyde. This deterioration was probably due to inversion of sucrose, as there were no indications of fermentation. In view of the very large saving of labor and fuel, and often of sugar in the event of breakage of the machinery, the slight deterioration of the juice, preserved with formaldehyde, is insignificant.

The cost of formaldehyde in barrels is so small that it would usually be advisable to employ it in larger quantities than is indicated above. It practically all disappears from the juice in the evaporation.

CRYSTALLIZATION OF THE SUGAR.

36. The Vacuum-pan.—The sirup obtained in the concentration of the juice still contains 45 per cent or more of water. This content of water could have been largely reduced in the multiple-effect, but to facilitate the graining of the sugar further evaporation is conducted in a vacuum-pan, in single-effect.

The modern vacuum-pan is usually a vertical cylindrical vessel, of cast iron, with a conical bottom and is fitted with a number of copper steam-coils and has a large door or strike-valve at the bottom, for the discharge of the sugar. The roof or dome of the pan is connected with a save-all and condenser by a large vapor-pipe and with a vacuum-pump directly by the vapor-pipe or by a small pipe, according to the type of pump. The vapor-pipe is usually made very large, that the velocity of the vapors may be comparatively slow, thus reducing the entrainment of sirup. The pan is also provided with eye-glasses or lunettes through which to observe the progress of the boiling liquor, and a proof-stick for the removal of test samples. The apparatus is so arranged that the panman can vary the temperature of the boiling liquor by increasing or decreasing the vacuum which is produced by the pump and condenser. The pump is said to be of the "wet system" when all of the condensing-water and the condensed vapors are passed through it. The vapors are condensed in a special condenser, when using a pump of the "dry system," and flow with the condensing-water through a torricilian tube or "leg-pipe" to a hot well and thence from the factory. The air is led off in a separate pipe and removed by the pump.

The pan as described is of the usual form. Various types of vacuum-pans are used. These vary in the extent and

arrangement of the heating surfaces, in the relation of the height to the diameter of the pan, and in the use or absence of special devices to promote the circulation of the boiling mass.

37. Boiling Sugar to Grain.—In order to facilitate the description of pan-boiling, and to familiarize the chemist with factory terms, a few expressions used by sugar-boilers will be first given. These expressions differ somewhat in the cane, beet, and refining branches of the industry. Only those customary in cane-work will be given:

The concentrated juice is called "sirup" or "meladura," the latter word is Spanish and is used by foreigners in Cuba and other parts of Spanish-America. The concentrated mass of crystals and molasses form the "massecuite," or when boiled partly with sirup and partly with molasses, "mixed massecuite," and each boiling is called a "strike." When a portion of a strike is removed from the pan and the remainder is left as a footing or nucleus upon which to boil another strike, the portion so left is termed a "cut." There is some confusion in regard to the use of the word "cut," as many sugar-boilers use this word for the massecuite removed from the pan. The process is termed "cutting."

Where two or more pans are worked side by side they are often connected with one another by large pipes, with suitable valves, for drawing the massecuite from one to another. These are called "cut-over pipes."

In modern practice, when a grained strike reaches a certain stage, diluted molasses is drawn into the pan instead of sirup and it is said to be "boiled in," or "boiled in on grain-sugar."

When the liquor in the pan has been concentrated to a certain density and is more or less saturated with sugar, it is said to have reached "proof." The proof may be "strong" or "weak" as the liquid is of greater or less density. This expression is still further modified, as will be explained in connection with the boiling of molasses-sugars.

The process of boiling sugar is as follows: The pan is closed, the vacuum pump is started, and when the gauge shows a vacuum of 15 to 20 inches of mercury, the charge-valve is opened and sufficient sirup is drawn into the pan to cover the coils. Steam is turned into the coils and the

sirup is rapidly concentrated to proof. The quantity of sirup used depends upon whether the boiler wishes "to grain" high or low in the pan. In making fine-grained sugar he will grain high, as he needs many crystals and comparatively little room for their growth; on the contrary, in making coarse-grained sugar he will grain low, and form few crystals.

As the liquor boils down, the steam-valves of the upper coils are successively closed, and as it becomes more and more concentrated, the portions projected against the eye-glasses flow more and more slowly and the panman increases or decreases the quantity of water injected into the condenser until the liquor boils at the desired temperature. At this stage there are two methods of procedure: (1) The concentration is continued until the liquor is sufficiently supersaturated with sugar, as is indicated by a sample drawn by the proof-stick. The water of injection into the condenser is now increased and the steam-pressure on the coils reduced, thus cooling the boiling mass, increasing the degree of saturation, and forcing minute crystals of sugar to form. These manipulations vary somewhat according to the vacuum-pan itself and the quality of the sirup, but in general are as described. (2) The second method of graining is that usually employed in the United States. The concentration of the liquor is continued until crystals of sugar separate, and when the panman considers that there are sufficient crystals he raises the temperature of the pan and injects more sirup. The first method produces a sugar of more uniform grain than the second, since all of the crystals required are formed at once.

After the crystals are formed, sirup is drawn into the pan from time to time as the water evaporates. This charging of the pan with sirup, and judging just when to charge, requires much skill and practice on the part of the boiler in order to secure the best results. If he injects sirup when the mass is too concentrated, with the liquor surrounding the crystals too rich in sugar, fresh crystals will be formed and must be remelted. These crystals are termed "false grain," and where formed at a late stage through carelessness of the sugar-boiler and are not removed, they impede or even prevent the curing of the sugar in

the centrifugals. False grain may be formed by charging the pan too freely with sirup, or by cooling the massecuite while the sirup surrounding the crystals is rich in sugar and of such density that it is supersaturated at a lower temperature. Also, if a sufficient number of crystals have not been formed when graining the strike, there is great risk of the formation of false grain, after the crystals have grown to large size. If the false grain is formed and not removed at this stage of the boiling, the sugar cannot be purged of molasses. False grain is gotten rid of by raising the temperature of the pan and drawing in additional sirup to melt the fine crystals.

As already stated, as the water is evaporated, sirup is drawn into the pan from time to time until the strike is finished. The massecuite is kept very free, i.e., of comparatively low density, until the crystals are large or the pan is about two-thirds filled. At this stage it is gradually boiled dryer and dryer until near the end of the operation, thus impoverishing the molasses surrounding the crystals, and finally the massecuite is evaporated to an apparent degree Brix of about 93, and is then discharged from the pan. The massecuite should be as cold as possible at this stage.

There are various methods of estimating the proper moment for striking the massecuite, i.e., discharging it from the pan. This is usually determined by withdrawing a sample with the proof-stick and forming it into a conical heap upon the thumb with the finger. The consistency of this massecuite, as shown by its appearance, rate of flattening, etc., are noted by the sugar-boiler, and a practiced man can in this way judge within narrow limits when to drop the strike.

During the boiling, care must be observed after each charge of sirup to concentrate the mass sufficiently to force the sugar to deposit itself upon the crystals already present and not to form new ones. Unnecessary concentration causes a waste of time and steam.

A method of charging a pan with sirup, employed with many vacuum-pans, but not applicable with all, is by means of a "set feed." After the formation of the grain the charge-valve is opened and so adjusted that the flow of sirup into the pan just compensates for the evaporation. The opening

of the valve is adjusted from time to time as the concentration varies, with variations in the steam-pressure, the density of the sirup, etc. This method of charging, with the first method of graining, produce a very uniform quality of sugar, and a very good yield from the massecuite. An irregular grain, with many minute crystals, from false grain that has not been melted, results in a low yield of sugar from the massecuite.

In boiling a massecuite so as to obtain the maximum yield of sugar from it, the full number of crystals required should be formed at graining, and the crystals should be of moderate and very regular size. Of course, false grain at any stage of the operation must be avoided. The formation of too few crystals results in rich molasses, since there is not sufficient crystal-surface to take up the sugar, and besides increases the risk of the formation of false grain. When boiling a strike on a very small nucleus of massecuite or on a small cut, there is also risk of false grain or of a partially exhausted molasses.

The temperature to be maintained in the massecuite during boiling varies with the desired grade of sugar, whether hard or soft, white or raw. American practice also differs somewhat from that of Java in respect to temperatures. The Java superintendent prefers relatively low temperatures. As will be noted in the chapter on sugar-refining, page 119, hard sugars are boiled at 180° F. in the American refineries, with no inversion. Similar but lower temperatures are customary in the white-sugar factories of Louisiana.

Hard sugars, as stated, are boiled at high temperatures, but they may also be produced at moderate temperatures from sirups of low densities. High-test raw sugars should be grained at temperatures approximating 160° F., and the high temperature should be continued until the grain is well developed. The temperature may be lowered in the latter part of the strike to promote reduction of the purity of the molasses surrounding the crystals. Massecuites that are to be further crystallized either in motion (crystallizer massecuite) or at rest in tanks should be boiled at as low temperature as possible.

In making a very soft sugar, after graining, the tempera-

ture of the boiling massecuite should be maintained as low
as possible. Low-pressure pans, *i.e.*, pans having large
heating-surface and utilizing steam of below 10 lbs. pressure,
are usually preferred for soft-sugars.

38. Methods of Sugar-boiling.—*Pan-room Defini-
tions.*—Raw sugar manufacturers often designate their
vacuum-pans by the letters "A," "B" and "C," as in re-
fineries, or number them, to distinguish the grade of masse-
cuite and not the pans themselves. A pan is usually always
employed in boiling the same grade of sugar in a refinery on
account of its proximity to a certain mixer and set of centrif-
ugals, but this is not usually true in a factory.

With the complications introduced into pan practice by
boiling-in molasses, it is simpler to designate massecuites
by names rather than numbers. Formerly when only
"straight-sugars" were boiled, the strikes were numbered
"first," "second" and "third." The first strike of masse-
cuite was boiled with pure cane-sirup, the second with first
molasses and the third with second molasses. At present
all the pans may be boiled in part with molasses, hence
there is some confusion in the nomenclature. When three
massecuites are boiled with return of molasses, the writer
prefers the following designation for each: (1) First masse-
cuite, containing only sirup or sirup and a very little first
molasses. This is therefore a massecuite of high coefficient
of purity. (2) Mixed massecuite, containing a footing of
massecuite from a first pan and a large proportion of first
molasses. This is of medium purity, approximately 75° to
80°. The first and mixed massecuites will produce the same
grade of raw sugar. (3) Second or crystallizer massecuite.
This massecuite is of low purity, usually of 60° and upward.
In many factories but two massecuites are boiled, in which
case that of the second boiling is termed "mixed" or "sec-
ond." The first massecuite in this method is reduced to
about 75° purity with first molasses.

Utilizing these definitions, the methods of pan-boiling
applicable with rich tropical cane in raw-sugar work will be
described. These methods are rapidly extending in Cuba
and possibly elsewhere.

The boiling-back of molasses has been practiced in Louisi-

ana for more than thirty-five years, especially in making grocery-sugars. The mixed massecuite was often termed "grain seconds." With the advent of crystallizers the present methods of boiling were developed simultaneously in Louisiana, Cuba and Java. The work in the East Indies was apparently based entirely upon European methods, and that in Cuba upon Louisiana and beet-sugar methods.

Three-massecuite Method. — A first massecuite is boiled of the purity of the cane-sirup. If the sirup purity is above 87°, it is sometimes necessary to inject some first molasses into the first pan to obtain a sufficient fall in purity from sirup to molasses. If the fall in purity is insufficient it may be difficult to exhaust the final molasses to a low purity in three stages. In boiling the mixed massecuite, a "cut" of massecuite from a first pan is used as a nucleus or footing upon which to start the strike. The writer has recently slightly modified this procedure in several factories, as will be explained farther on. The mixed massecuite should have a purity of from 75° to 80°. The purity of this massecuite is governed by the desired purity of the second molasses, for which a purity of 52° is a convenient number. The purity to be given the second or crystallizer massecuite depends upon several factors, viz., vacuum-pan capacity, crystallizer and centrifugal capacity and the desired exhaustion of the final molasses. The lower the purity of this massecuite the longer is the time required in boiling the strike. A very low purity massecuite must remain a long enough time in the crystallizers in order to reduce its viscosity by crystallization of the sugar and promote rapid purging. Where molasses is sold upon a basis of a certain sugar content, this also must be considered in fixing the purity of the second massecuite. For obtaining final molasses of apparent purities below 30°, early in the season in the Tropics, and from 30° to 35° when the cane is ripe and of very high purity, the massecuite should be reduced to approximately 60° purity. Where the pan, crystallizer and centrifugal capacities are large, the purity may be reduced below 60° with correspondingly lower final molasses purity, but this would not usually bring a sufficient return for additional investment and fuel.

The first and second massecuites may be purged imme-

diately after leaving the vacuum-pan, and should produce
the same grade of sugar and molasses of widely different
purities. The second or crystallizer massecuite is purged
after remaining three or four days in the crystallizers. This
massecuite yields a sugar that may be sold as seconds, or
preferably, since it is a "grain" sugar it may be converted
into sugar equal to the firsts by double purging.

It should be noted that in boiling-in molasses this should
be accomplished after no more sirup is required by the strike.
The molasses must be free of sugar-crystals and should be
warmer than the massecuite in the pan. It should be reduced
to a density of about 54° Brix, at pan temperature.

Massecuites Boiled with "Seed."—In a method practiced
largely in the Hawaiian Islands and Java the strike is started
upon a footing of magma formed of string-sugar mingled with
sirup. Grain upon which to build in this way is popularly
called "seed." A sugar of good grain and test may be made
in this way, and without remelting of string-sugar the factory
may produce a single grade of product.

The writer has recently introduced a slightly different
method of boiling with seed in Cuba. The difference is only
in the source of the seed. The grain-sugar obtained from the
second or crystallizer strikes is mingled with first molasses to
form a magma. This magma is used preferably as a footing in
starting mixed strikes which are finished with first molasses,
but it may also be used in first massecuites. The magma is
stored in a crystallizer, with motion, and is always available
without loss of time and in this respect is preferable to cutting
massecuite from another pan.

The following is a convenient pan method: The first
pan is boiled without molasses, except when the sirup
purity is very high. A second (mixed) massecuite is boiled.
A third (crystallizer) strike is boiled on a footing of first
massecuite. The molasses from this massecuite is final.
The crystallizer sugar, unwashed, is mingled with first
molasses and serves as a footing in the mixed pan upon
which to boil first molasses. Working with cane of very
high purity, it may be necessary to mingle the crystallizer
sugar with second molasses. This method produces a single
grade of product of very strong grain and any desired test.

Boiling Molasses-sugars.—In many factories, not equipped for the process of crystallization in motion, after two crystallizations in the vacuum-pan, the molasses is boiled to what is variously termed " string-proof," "smooth," " blank," etc.

The molasses is first heated in a blow-up tank, *i.e.*, a tank fitted with perforated steam-pipes instead of coils. This heating is for the purpose of melting such crystals of sugar as may have passed through the sieves of the centrifugal machines, and often for further purifying the molasses. Many sugar-makers add lime to the molasses at this stage to neutralize its acidity; others use caustic, and still others carbonate of soda. The carbonate of soda neutralizes the acidity and if added in sufficient quantity breaks up the lime salts, at least to some extent. Carbonate of soda is frequently drawn into the pan with the molasses and apparently, in the author's experience, with advantage. The soda is preferable to lime.

In boiling molasses to string-proof, it is simply drawn into the pan and boiled down to the proper density. The determination of this density, by the usual tests of a sample drawn to a "string" between the finger and thumb, is a matter requiring much judgment and experience. The required proof varies with the purity of the molasses and the kind of containers used in crystallizing the sugar. In this crystallization at rest, as distinguished from the modern process of crystallization in motion, the crystals formed slowly settle to the bottom of the car or tank, gaining slowly in size, never becoming large. Such sugars range in polarization from 80° to 90°, varying in test with the quality of the molasses and the skill displayed in the pan-boiling. A suitable density for the massecuite is approximately 89° to 90°, apparent Brix.

The sugars from mixed strikes, boiled on footings of massecuite grained in the pan, though boiled with molasses, are not " molasses sugars " in the commercial acceptance of the term. Molasses sugar is obtained from massecuites boiled to " string test " and crystallized at rest. Such sugar has a soft crystal and is permeated with molasses. The mixed strikes are " grain " sugars, and when well boiled are equal to first sugars except in color.

39. Crystallization in Motion.—This process was first used in the European beet-industry. Cane-sugar manufacturers were slow in abandoning string-sugar methods, and when crystallizers were first introduced the strikes were boiled blank and run into them. As the name implies, this process consists essentially in keeping the crystals of a massecuite in motion while completing the crystallization. The best results are therefore obtained in pushing the crystallization so far as is practicable in the vacuum-pan and completing it in the crystallizer.

A theory of the process [1] that conforms with the writer's experience with cane-sugar is as follows: If the crystals of a massecuite be kept constantly in motion and be brought intimately in contact with the sugar still in solution, this sugar will deposit upon the crystals already present rather than form new ones, provided there is no sudden reduction of temperature to increase the supersaturation. Manifestly it is impossible to produce a stirring device that will move each crystal independently, in the heavy, viscous massecuite, to entirely new environment, so that it may be brought into contact with fresh portions of the sugar in supersaturated solution. Further, there is little possible freedom of motion for a crystal in a dense massecuite, since the film of molasses separating it from its neighbors is but a few thousandths of an inch in thickness. The crystal gradually takes on the sugar in its own immediate neighborhood, reducing the density and viscosity of the molasses surrounding it, and in its increase of size it approaches nearer a fresh source of sugar. Great inequality of density cannot long exist, since the stronger solutions near by must mix with the weakened solution by diffusion. The motion of the stirrers of the crystallizer, by rocking the crystals, promotes this diffusion and a uniform fall of temperature in the massecuite. With the fall of temperature, the saturation of the solution resulting from the growth of the crystals is changed to supersaturation and crystallization continues. A point is finally reached when the crystal size ceases to increase. This is due to the vis-

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[1] " Crystallization of sugar in after-product massecuites," H. Classen, Int. Sug. J., 14, 284.

cosity of the medium and not to lack of a supersaturated solution of sugar. When this point is reached, the masse-cuite should be diluted with water or if preferred with dilute molasses. Diffusion is again possible and the crystallization again progresses. The dilution must be repeated from time to time for the best results. Water is preferable to molasses as a diluent since it does not add solids to the massecuite.

From the above remarks, it is evident that the massecuite should be boiled to very high density before discharging it into the crystallizer and should not be diluted with molasses in the vacuum-pan. Dilution should begin the moment the fall of temperature has increased the viscosity so much that the crystallization no longer progresses. With practice this condition may readily be determined by observation of the massecuite while in motion in the crystallizer. It is prefer-able to promote diffusion by dilution of the massecuite rath.r than by boiling to low density.

The method of boiling massecuites for crystallization in motion and preferred by the writer is described in the " three massecuite methods," page 91. There are three other meth-ods of operating, but they have not been entirely satisfactory in the author's experience, except the second, which he has used to a limited extent on account of a local condition: (1) A grain strike is boiled as is usual and a part of it is discharged from the pan; hot molasses of about 90° Brix is drawn into the pan and is mixed with the massecuite remaining by boil-ing. When the mixing is completed the strike is discharged into a crystallizer. (2) A strike of mixed massecuite is dis-charged into a crystallizer and mixed with a string-strike of higher temperature and moderate density that is flowing from an adjacent pan. (3) A magma of molasses and string-sugar is drawn into the pan and heavy molasses is mixed with it as in the first method.

There is always great danger in these methods of forming false grain. The writer has used the second method in a factory deficient in pan capacity with a fair degree of success. There is difficulty in mixing the molasses with the massecuite or magma in these processes.

Among the advantages of crystallization in motion over the older methods, are a saving of labor and floor space,

cleanliness, the production of grain-sugars and the ability promptly to liquidate the factory at the close of the manufacturing season. No massecuite need be carried forward to the next season, thus avoiding loss by fermentation.

Laboratory Control of Crystallization in Motion.—The apparent Brix and the purity coefficient of the massecuite should be determined to control the density of the massecuite and the admixture of molasses. A sample of the massecuite should be purged in the laboratory apparatus immediately after leaving the pan. The molasses from this should be tested for purity. The immediate molasses from a sample of masscuite of 60° purity in the Tropics should have a purity below 40°. A fall of at least 20° from massecuite to molasses may be expected. The further fall in purity to final molasses depends upon the condition of the cane, and will be less in the Tropics than in Louisiana. The Louisiana cane never matures and therefore the initial purity of the juice is never as high as in the Tropics. The total fall in purity in the Tropics is from 55° to 60° and in Louisiana from 50° to 55°. A final apparent purity number of 25° may be expected early in the tropical season while the cane is immature.

Crystallizers.—The usual crystallizers are of three types, the third of which is now little used in cane-sugar works: (1) Closed crystallizers. This is a horizontal cylindrical vessel fitted with a powerful spiral stirrer. A water-jacket for control of temperature was provided with the original Bock crystallizers. These jackets are now little used in cane-sugar factories. (2) Open crystallizers. These are simply open tanks of half-cylinder cross-section, fitted with stirrers as in the closed type. (3) Vacuum crystallizers. These are closed crystallizers provided with vacuum-connections and a steam-jacket at the bottom. This crystallizer is in fact a slow-boiling vacuum-pan with forced circulation of the massecuite.

The large extension of present-day factories has led to the discharge of the massecuite from the pans into the crystallizers through pipe-lines. Moderate air-pressure is applied in the pans to force the massecuite through the pipes. The pipe-lines should have an internal diameter of not less than

14 inches, especially if the crystallizers are located far from the pans.

Crystallizers are used to some extent for the storage of first and mixed massecuites pending an opportunity to purge them. From the point of view of the crystallization, it is unnecessary to use crystallizers at this stage to further exhaust the molasses.

40. Solidified Molasses.—So far as the writer is informed, this product is produced only in Java and for shipment to British India for arrack manufacture.

The manufacture of solidified molasses requires no special apparatus. Molasses is first " blown-up " with steam and skimmed and is then simply evaporated to dryness in an ordinary vacuum-pan operating with a very high vacuum. Serious frothing is liable to occur. The proof-stick samples are tested by cooling in water. The cooled sample should have the characteristics described below. The dried molasses, a molten mass, is run into closely woven baskets while it is very hot and solidifies on cooling. The tops of the baskets are covered with burlap for shipment.

The vacuum-pump should be operated for a short time after shutting off the steam from the pan to partially cool the molasses. Cooling by the circulation of water through the coils is also practiced. Gases are produced by decomposition, therefore the pump should not be stopped until ready to break the vacuum.

The usual commercial specifications for this product are as follows: (1) The solid molasses shall break with a clean fracture; (2) it shall sink in water; (3) it shall be too hard to indent with the finger nail.

J. J. Hazewinkel [1] examined solidified molasses to determine whether loss of dry substance occurs during the manufacture. He analyzed the molasses before and after drying, and calculated the results to a basis of the ash content of the original material, assuming it to be a constant. His conclusions were as follows: (1) There is considerable loss of dry substance. (2) The extent of the decomposition is dependent upon the temperature. (3) The reducing sugars

[1] Archief, 1912, 20, 181.

in part pass over to organic non-sugar. (4) It is possible that to some extent loss of dry substance is due to decomposition of both reducing-sugar and organic non-sugar. (5) About equal parts of dextrose and levulose are decomposed. In view of the proportions of dextrose and levulose it is probable that polymerization of dextrose to levulose takes place during the long heating.

41. Froth "Fermentation."—When massecuites are boiled at high temperatures they often foam and run over the sides of the containers. The foaming may begin immediately or some hours after striking. This phenomenon is termed "fermentation" or "froth fermentation." It is only in recent years that we have a fairly definite knowledge of the cause of the foam. It is not due to fermentation, that is, to bacterial activity, but to the decomposition of certain salts.

Herzfeld [1] states that Kraisy has recently shown that Lafar's results on the reaction of the invert-sugar with amino acids, e.g., glutamic acid, splitting off carbonic dioxide, is the cause of foaming. Massecuites (sugar-beet) foam suddenly when a temperature of about 65° C. (149° F.) is reached. Kraisy explains the phenomenon by the carbon dioxide remaining in supersaturated solution until the formation of sugar crystals catalyzes its liberation. The viscosity of the massecuite results in foam. Herzfeld also states, always referring to the beet industry, that foaming is rare since the introduction of phenolphthalein for rosalic acid in alkalinity tests. Lime will stop the foaming.

The usual method of stopping foaming in a cane-sugar factory is to pour water upon the surface of the massecuite. This reduces the viscosity and facilitates the escape of the gas. Cane massecuites that have not been heated above 156° F. do not usually foam. The same conditions as those observed in beet-sugar manufacture are probably the cause of foaming in cane massecuites. A crystallizer should always have provision for escape of the gases or preferably should be uncovered except while discharging by air-pressure. .

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[1] Zeit. Ver. Zuckerind., 64, 543.

PURGING AND CURING THE SUGAR.

42. Centrifugal Work. Curing and Packing.—
The sugar is purged of molasses by centrifugal force in a
machine called a " centrifugal." This machine is essentially
a perforated drum or basket so arranged that it may be
revolved at high velocity. The basket revolves within an
iron casing which serves to catch the molasses and lead it
to the conduit. The basket is lined with a finely perforated
sheet of bronze or with woven-wire cloth. The machines
in the older factories and in most small ones usually have
baskets 30 inches in diameter by 14 to 18 inches in depth,
though sometimes the 36-inch centrifugals are used. The
large factories and most small ones of recent construction
use centrifugals whose baskets are 40 inches in diameter and
24 inches deep and upward. The centrifugal of 30 inches
diameter is usually revolved at a speed of 1200 to 1400
revolutions per minute and the large machines 1000 revo-
lutions.

The masseccuite is fed into the machines from a mixer
which prevents the crystals from settling. The centrifugal
usually receives its charge of masseccuite while it is in motion,
though it may be charged at rest. The basket is spun until
the sugar is practically free of molasses. The molasses
passes through the perforations of the lining and the crystals
are retained. In making high polarization sugars and a
white product, so soon as the surface of the wall of sugar
appears in the centrifugal, indicating that little molasses is
left, it is washed with water or special washes. This treat-
ment removes the film of molasses that adheres to the
crystals. Special washes are occasionally used to color the
crystals to meet certain market conditions, e.g., the Demarara
crystals.

Centrifugals are sometimes arranged with double gutters
to classify the molasses. After washing begins the molasses

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is directed into the second gutter and is returned to the pan-room for reboiling with rich sirup. This arrangement is not very satisfactory on account of the lagging behind of the heavy molasses first thrown off, which in part mixes with the wash. The classification is better accomplished by double purging as described farther on.

Each sugar-drier or purger usually manipulates two centrifugals. It is necessary to place a man at each large machine to work these to their full capacity in drying very free purging sugars. A 40-inch by 24-inch centrifugal, driven by belts and working with one operative to two machines, should purge from 4000 to 4800 lbs. of 96° polarization sugar per hour, the quantity varying with the skill of the operative, the quality of the massecuite and the facility with which the centrifugal may be started and stopped. This capacity may be increased by the use of mechanical dischargers, or self-discharging baskets.

The discharger is a plow arrangement that is lowered into the basket and directed against the wall of sugar. The basket is revolved slowly against the plow, which cuts down the sugar and pushes it out of the machine by the bottom valve.

The self-discharging basket has a steep conical section at the bottom and may or may not have a discharge-valve. The type without discharge-valve has a deflector on the spindle or shaft to direct the massecuite toward the wall of the basket. In the other type, the valve may be raised while the centrifugal is running. The machine with a deflector is charged with massecuite while running. When the sugar has been purged and the centrifugal is stopped the sugar usually falls out of it without assistance. In the other form it is necessary to lift the valve before the centrifugal is stopped. These machines should be used only with freely purging sugar of strong grain.

The manufacture of white sugar demands special care in purging. The sugar is washed in the centrifugal with large quantities of water, upward of six gallons being required per charge in a 40-inch machine. A small quantity of ultramarine is often added to the wash water to kill the yellow tinge of the sugar. The method of double purging gives the best results in washing plantation white sugars

Two sets of centrifugals are necessary for double purging. The sugar is purged in the first set without washing or with very little water. It is then " cut down " into a mingling device and formed into a magma with sirup from the second purging. The magma is elevated to the second mixer and is purged in the second set of centrifugals with thorough washing.

Double purging serves a two-fold purpose: It separates the dark, low-purity molasses of the first purging from the rich, light-colored sirup of the second. This sirup is of the suitable color and richness to permit reboiling with cane-sirup to make white sugar. The mingling process mixes the crystals thoroughly with the light-colored sirup. The friction of crystal against crystal promotes the removal of the adhering film of molasses.

Double purging was introduced into Cuba by the writer to facilitate the handling of crystallizer-sugar in the production of one grade of sugar and final molasses. The crystallizer-sugar is purged without washing and the molasses from it is final. The sugar is discharged into a mingling screw-conveyor and transferred to the mingler proper. The conveyor-screw is lubricated with first molasses diluted to about 78° Brix, and this molasses is also used in the mingler to form the magma. The mingler is simply a mixer. The magma is pumped to the first machine's mixer for immediate purging or to a storage crystallizer to be used as a footing or "seed" in boiling massecuites.

Raw sugars are usually packed in bags for shipment, and in Cuba, without further drying than they receive in the centrifugals. Their moisture may be reduced by the use of superheated steam in the centrifugal. Raw sugars may also be dried in granulators or driers such as are used in the refineries (see page 120) provided they are of high test and clean crystal. This method of drying is very liable to result in a product that will harden or cake in the packages.

The usual Cuban sugar bag holds from 325 to 330 lbs. of centrifugal sugar and measures 29 inches by 48 inches and its tare is approximately 2.5 lbs.

White sugars may be dried in the granulator or dryer or with superheated steam in the centrifugal. The crystals

lose a part of their gloss in the granulator through friction
with one another. The American market is accustomed to
such sugar and possibly prefers it. The gloss is preserved
in drying with superheated steam and it is such sugars that
are made in Java for the home and East Indies markets.
The steam should be heated to about 200° C. in a separate
boiler.

Various types of conveyors are used in transferring sugar
from the centrifugals to the packing-bins. Sugar should not
fall directly from the centrifugal into the package, since under
this condition it cannot be of uniform quality, and besides
may harden. Three types of conveyors are in general use:
(1) Ribbon- or screw-conveyor. This is a screw or spiral
ribbon that revolves in a trough and carries the sugar with
it. The cross-section of the trough should be a parabola.
(2) Endless belt. The belt is often of curved-steel slats
attached to a chain. This is a very efficient device, but has
the objectionable feature of leakage of sugar. (3) Grass-
hopper conveyor. This is a very efficient conveyor that is
used very generally in factories of Scotch design. As is
implied by the name, the motion of the conveyor is something
like that of a grasshopper. A trough is arranged to move
slowly forward, carrying the sugar, and then pull backward
very quickly, leaving the sugar. Each stroke advances the
sugar a certain distance. All parts of the conveyor are easily
accessible for cleaning.

Sugars should be cooled to atmospheric temperature
before packing them, otherwise they usually cake in the
package.

43. Classification of Raw Sugars.—The basis of the
American market is usually a centrifugal sugar polarizing 96°.
This sugar must be grained in the vacuum-pan. The cor-
responding sugar in Java is of higher test and is there called
" muscovado," and in the American market " Javas." Under
certain market conditions the test upon which the price is
based may be 95° instead of 96°. The next grade is 89°
molasses sugar or seconds. This was formerly always a sugar
crystallized at rest, but now low-testing grain-sugars are
included. Muscovado sugar is that made by open-air evapo-
ration and crystallization in coolers at rest. The molasses

is removed by simple drainage. The bulk of the raw sugar product of the Tropics is of the 96° grade.

Raw sugars entering the United States were formerly classified according to the Dutch color standard. Certain countries, notably Japan, still retain this standard. The Dutch Standard is a series of sugars ranging in color from a very dark brown, numbered 7, to an almost pure white sugar, numbered 25. These samples are prepared annually in Holland. They are supplied to the sugar trade in small square bottles of the uniform glass and size. Tropical 96° sugar usually falls below No. 16 of this standard.

44. Classification of White Sugars.—The classification of the sugars produced by the American refineries is given on page 122. The plantation product is usually called Plantation White or Granulated. Java white sugars in order to meet the market specifications of the East Indies must grade above No. 25 Dutch Standard.

45. Conversion of Low-grade Sugars into High Grades.—The method of making a single grade of sugar without remelting the low sugars is described elsewhere in this chapter. Low-testing grain-sugars and string-sugar are frequently remelted and reboiled to higher grades. Remelting is unnecessary with grain-sugars, since they may be mingled with molasses and be repurged to sugar of high polarization. String-sugar must be used to " seed " a pan or be remelted in juice or water for reboiling. Remelting results in a part of the sugar being reboiled several times with the accompanying decomposition losses. The remelting of string-sugar may introduce bacterial organisms into the products that may cause serious deterioration in storage.

46. Deterioration of Sugars. Warehousing of Raw Sugar.—The storage of raw sugar with avoidance of losses through fall in its polarization has been a subject of much study.[1] The size and hardness of the crystals, the cleanliness of the factory and process, the packing conditions, the moisture content of the sugar or the composition of the residual sirup on the crystal and the character of the ware-

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[1] See also " The Deterioration of Sugars on Storage," Noël Deerr and R. S. Norris, Bul. 24, Expt. Sta. Haw. Planters' Ass'n.

house itself, all influence the keeping qualities. It is also possible that washing the sugars in the centrifugals, without following this with thorough drying in the machines, has an adverse effect in storage on account of the dilution of the film of molasses on the crystal. Claassen [1] observed that when the film of molasses surrounding the crystals is super-saturated the microorganisms cannot develop and that the sugar has good keeping qualities. Deterioration is generally believed by investigators to be usually due to bacteria and yeasts.

A sugar composed of large crystals presents less area for moisture absorption than one made up of small crystals. A hard crystal will have little molasses adhering to it or pene-trating it. Molasses is hygroscopic and when diluted with water affords an excellent medium for the activity of bacteria and yeasts. It may thus be seen that the combination of a large and hard crystal is favorable to good storage qualities.

Cleanliness of the factory and utensils cannot eliminate bacteria, but can reduce their activity. Further, there are fewer bacteria and yeasts in a clean than in an untidy factory. Cleanliness in the centrifugal work is very essential. The wash-water should be pure and the utensils for handling it should be kept in good sanitary condition.

The packing conditions may have an influence upon the keeping qualities. If a sugar is packed while too hot, it will sweat in the package and the moisture condition necessary to bacterial activity is thus supplied. The writer has noted a fall of several degrees in the polarization of standard granu-lated sugar that was undoubtedly packed while quite hot. It is not usually a simple matter in very large raw-sugar factories to provide cooling arrangements.

That the moisture content of the sugar has a very marked influence upon the keeping qualities is the consensus of opin-ion of many observers. It is now quite a well-known fact that very dry sugar will usually hold its polarization even in long storage. It must also be stored under sanitary conditions. The permissible upper limit of moisture is not well established, but it has been very generally observed that

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sugars polarizing less than 97° and containing less than 1 per cent of moisture when warehoused suffer very little deterioration. If stored in a dry place, without exposure to damp currents of air, such sugars may even gain in polarization through loss of moisture.

The application of the formula of the Colonial Sugar Company, Australia, is of great value in judging whether a sugar may be expected to conserve its polarization:

Per cent moisture in sugar $\div$ (100 $-$ polarization) $=$ <0.333.

In other words, that a sugar may not suffer deterioration in storage, the ratio of its moisture to its non-polarization should be less than 0.333. Experience indicates that this ratio should be somewhat smaller for Cuban sugars.

Gain of polarization is not always an indication that a sugar has not suffered a loss of sucrose. Such loss may be offset by a greater one of moisture, thus giving the sugar a polarization higher than in the original test. Decomposition of the levulose might cause a small rise of test.

The full specification of a suitable warehouse is difficult to make. It is certain that the warehouse should be large and dry. There is difference of opinion as to whether it should be almost hermetically sealed during storage or open for free ventilation. The warehouse should undoubtedly be closed on damp days on account of the deposition of moisture on the sugar with the reduced night temperature. The writer believes that it is the safer plan to close the warehouse tightly when practicable.

Approximately 6 cubic feet warehouse capacity should be provided per 325-lb. bag of sugar and 6.5 square feet of floor-space.

SUGAR REFINING [1]

47. Introductory.—The process of refining is simple in theory, but very complex in actual practice. The working up of the lower-grade materials, the handling of the sweet-waters and the control of the char filtration involve an enormous amount of detail, much of which cannot be fully considered in this chapter.

The narrow "margin" or difference between the prices of raw and refined sugars has tended to cause the concentration of the industry into large units. The matter of shipping facilities and the increasing number of fancy grades of refined sugar have also helped in bringing about this concentration. Practically all of the refined sugar used in the United States is now produced in a few large refineries situated in the principal seaports.

48. Definitions.—Refineries are of two classes: Those producing only the pure white granulated sugar and its modifications and those which manufacture both granulated sugar and the soft white and yellow sugars of lower purity. These refineries will be referred to in this chapter as "hard-sugar" and "soft-sugar" refineries respectively. It must be borne in mind, however, that the soft-sugar refinery also produces hard sugars. The two types of refineries use essentially the same process, the soft-sugar refineries, however, employing all expedients which will give fine color to their lower-grade liquors.

The term "liquor" is used in refining to refer to a sugar solution from which no sugar has been removed by crystallization. "Sirup" refers to a solution from which sugar has already been crystallized. A "sweet-water" is a wash-water

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[1] By George P. Meade, Superintendent of the Cardenas Refinery, Cuba. The methods described here apply especially to sugar refining as it is conducted in the American refineries.

which contains sufficient sugar to make it worth evaporating for further crystallization. A "magma" is a mixture of sirup and crystals and corresponds with the massecuite of the raw-sugar factory.

49. Raw Materials.—Centrifugal sugars of about 96° test form by far the larger proportion of the melt of the refineries. The present tendency, however, is for the raw-sugar factories to produce sugars of higher test than 96° with a view to obtaining better storage qualities. The lower-grade sugars, cane seconds or molasses-sugars, muscovadoes, Philippine mattes and concrete-sugars, palm-sugars, and others which come more rarely to the refineries, are mixed to give a melt averaging usually from 93° to 95° test. The proportion of low-grade sugars is varied from time to time according to the kind of refined sugars to be made, or the color of the raw sugars melted, or to suit market conditions. .

The character of the raw-sugars received by the American refiners is indicated by the following statistics of The New York Sugar Trade Laboratory: The average tests of all samples received during the years 1908 to 1914, inclusive, were respectively, 94.83, 94.88, 95.19, 94.96, 95.02, 95.71 and 95.15. During the year 1914 the distribution of the various grades was as per the following tabulation:

Sugar Testing.	Per Cent of the Total Number of Samples.
98-99°	0.924
97-98	9.453
96-97	38.602
95-96	31.037
94-95	8.041
93-94	3.005
92-93	1.009

The samples tested in 1914 show a marked increase in those testing above 96°, owing possibly to the elimination of the Dutch color standard from the American sugar tariff. The above figures show a tendency to the manufacture of high-test raw sugars and the influence of the crystallization in motion process (*see* **39**) in reducing the output of molasses-sugars.

The raw sugars arrive at the refinery in various kinds of packages. Jute-bags containing 300 to· 330 lbs. each are received from the West Indies. Hawaiian and Central American sugars are packed in smaller jute-bags. Java sugars are packed in palm-leaf baskets. Occasionally barrels and hogsheads are used for muscovadoes and concrete-sugars. Each package of sugar is weighed and sampled before it is dumped.

The raw sugar is dumped into bucket-elevators and is carried to· the minglers. Some of the larger refineries have recently installed storage-bins for raw sugars. These are placed above the minglers. The packages of sugar are hoisted directly from the ship and after weighing and sampling are emptied into the bins. Sufficient sugar is dumped during the day to supply the refinery for the twenty-four hours period. The sugar is fed continuously by scroll-conveyors from the bins to the minglers. This method of storage materially reduces the cost of handling the raw sugars.

The empty jute-bags are washed with hot water for the recovery of the adhering sugar, dried and sold. The wash or "sweet-water" is mixed with other similar solutions and is evaporated to a sirup and thus enters the manufacture. The palm-baskets are steamed and then burned under the boilers in specially constructed furnaces. Hogsheads and barrels are steamed and sold.

50. Washing the Raw Crystals.—The sugar enters the minglers, which are simply strong scroll-conveyors provided with mixing-flights, where it is intimately mixed with a sirup of 65-70° Brix to form a cold magma or "mash." This magma is immediately purged in centrifugal machines of the type used in raw-sugar manufacture. The resulting sugar is washed in the centrifugals by spraying it with a measured quantity of water. The purging and washing free the crystals of the coating of adhering molasses and yield a light-colored sugar of from 98.5 to 99 coefficient of purity. This process separates the raw material into two parts, one a sugar of very high purity and the other a sirup of comparatively low purity. This separation facilitates the manufacture and permits the simultaneous refining of several kinds of raw sugar, e.g., cane- and beet-sugar.

The "washed sugar" is dissolved in about one-half its weight of water in a tank provided with mixing-arms and called a "melter." In certain refineries, some of the higher grades of sweet-waters are used in melting, but the better practice is to use clean hot water. The melted sugar-liquor is pumped to the defecators.

The "raw-sugar washings," purged from the mash, have a coefficient of purity of approximately 80° and constitute from 14 to 18 per cent of the weight of raws melted. The amount of raw-sugar washings will be greater as the test of the melt is lower, and for sugars having a small or soft grain. A part of the undiluted washings is used to make the mash with succeeding raws and the remainder is diluted with water or dark sweet-waters and is sent to the defecators. In order to reduce sugar losses through material being on hand too long, it is usual to start the mash with fresh water once in twenty-four hours, all the washings on hand at that time being pumped to the defecators.

When very small, soft-grained low-grade sugars, such as muscovadoes and concretes, are handled, it is customary to melt them directly without washing. The resulting low-grade liquor is defecated and treated exactly the same as the washings.

51. Defecation.—The defecators or "blow-ups" consist of iron tanks, usually of 3000 gallons capacity, fitted with perforated coils through which exhaust or low-pressure steam may be blown into the liquor. The bottom of the blow-up is usually slightly conical to facilitate drainage and cleaning.

A great number of defecants have been experimented with for refinery work. Blood or blood albumen was formerly used as a coagulant and clarifier, but its use has been entirely discontinued. The defecating materials commonly employed are milk of lime and phosphoric acid. The phosphoric acid may be in the form of monocalcic phosphate, phosphoric-acid paste or a clear phosphoric acid.

The monocalcic phosphate is made in the refinery by the action of commercial hydrochloric acid upon bone-dust. This is called "black paste," and contains from 10 to 12 per cent of available phosphoric acid (P_2O_5). The black paste

contains chlorides and these are not absorbed by the char, hence increase the quantity of residual sirup. Phosphoric acid paste may be made in the refinery by treating bone-black dust with sulphuric acid. Pastes of this type may be found in the market under various commercial names. They are apt to have a high content of sulphates which will be largely retained by the char in the filters, increasing the sulphate content of the char. The clear phosphoric acid is made by treating bone-black dust with sulphuric acid and then filtering out the solids in wooden-frame filter-presses. The soluble sulphates are reduced to a minimum by diluting the phosphoric-acid solution to 15° Brix. The clear phosphoric acid, while a little more troublesome to make than the other two preparations named, is the most satisfactory of the three and introduces less soluble salts into the liquors.

The lime is introduced as a milk of about 20° Brix. The phosphoric acid is first added and the lime immediately afterward, usually in sufficient quantity to give a faintly alkaline reaction to litmus. If soft sugars are to be made, a faint acid reaction may be maintained to prevent the formation of dark-colored lime-salts. The amount of phosphoric acid used is determined by the class of sugar melted, low-grade liquors requiring in general more defecating material. A refinery handling sugars of 95° average test will use about 1000 lbs. of lime and from 500 to 600 lbs. of available phosphoric acid (P_2O_5) for each million pounds of raw sugar melted. After the addition of the defecants, steam is turned into the blow-up coils and the temperature of the liquor is brought to 180° F.[1] At the same time water is added to the liquor. The washed-sugar liquor is diluted to 54° Brix and the raw washings to 50° Brix, the densities being as determined in the hot liquor with a hydrometer.

The lime neutralizes the organic acids present in the raw sugar and the excess combines with the phosphoric acid to form tricalcic phosphate. The heating and defecants cause the precipitation of the greater part of the gums,

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[1] The Fahrenheit scale is used in all American refineries and is therefore used throughout this chapter.

albumins and pectins. The whole forms a heavy, flocculent precipitate which entrains with it the finely suspended materials derived from the raw sugar, bagasse-fiber, jute, etc. The defecated liquor or washings and low-grade sugar liquors may either be sent to separate bag-filters or they may be distributed over the filters which have been used for washed sugar-liquors, allowing a draining period after the high-grade liquor has been shut off.

52. Bag Filtration.—The American refineries use the Taylor type of filter. This filter consists of a cast-iron casing or box, the top of which is perforated at intervals with holes, each having a short nipple fitted into it from which is suspended a filter-bag or element. Each bag is made up of an outside sheath of loosely woven cord, about 6½ feet long and 6 inches in diameter, and an inside bag of cotton-twill fabric which is 6 feet long and 24 inches across. The inside bag being loosely crumpled in the sheath gives the effect of the fluted filter of the laboratories. A bronze connection, which may be screwed to the nipples in the holes in the top of the filter, is tied into the mouth of each bag.

The defecated liquor is run on to the top of the filter, which is surrounded by a shallow curbing, and flows down through the bags, the precipitate being retained. The filtered washed-sugar liquor is of a light-brown color, quite free of suspended matter or turbidity. The filtered raw-washings are also clear but of much darker color. After from fifteen to twenty hours' use the bags fill with mud and filtration becomes very slow. The liquor going on to the filter is now shut off and the liquor remaining in the bags is sucked out by a vacuum-pipe, or is allowed to drain out. The filter-bags are flushed once or twice with thin alkaline sweet-water from the filter-presses and the mud is further washed in the bags, as they hang in the filter-casing, by introducing a jet of hot water into each successively. This "sticking" is repeated from three to five times after which the bags are taken out of the filter and washed in a series of tubs to remove all the mud. The bag-filter sweet-waters are sent to the evaporator for concentration. The mud-water, i.e., the mud and water from the tubs, is limed, diluted and filter-pressed. The press-cake is discarded or sold for agricultural use, and the press-

water, filtrate, is used partly in flushing filters as mentioned above, and the remainder is evaporated to a sirup.

53. Char Filtration.—The char or bone-black filters are of the utmost importance in refining. The economy and efficiency of the refining process depend upon careful control and close attention to detail at this station. The filtration is carried on according to a definite schedule, each step in the operation being allotted a given amount of time. The entire operation, from the beginning of one filtration to the beginning of the next, is termed the "cycle" of the filter. The cycle will take from forty-eight to seventy-two hours, depending upon the speed at which the reburned char is drawn from the kilns.

Two systems of working char-filters prevail: The "set" or "battery" and the "continuous" systems. In the set-system, all the filters filled in one day are worked as a group unit, all the filters in the group doing the same class of work at the same time. In the continuous system, each filter goes through its cycle independently, a step ahead of the filter filled immediately after it. The set-system is used by soft-sugar refineries because it lends itself more easily to their pan-boiling system and also simplifies the use of double- and triple-filtration. The continuous system requires a much smaller char-filter installation for a given melt, so it is generally used in the hard-sugar refineries. The handling of any one filter in the two systems is essentially the same.

The filters are cast-iron vertical cylindrical cisterns, conical at the top and bottom, and usually about 10 feet in diameter and 20 feet deep. The top is closed by a movable door termed the filter-head. Two manholes at the sides near the bottom serve for the removal of the exhausted black. The char rests on a perforated plate covered with a coarse-weave cotton blanket, and this in turn with a blanket of finer weave, to prevent the char-dust being carried out with the filtered liquor. The inlet-pipe is at the side of the filter, close to the top, and the outlet is at the bottom, below the perforated plate. The outlet-pipe is carried up in a gooseneck on the outside of the filter to within a few feet of the top.

The filtering material is animal charcoal or bone-black.

This is the granular residue obtained by the destructive distillation of bones. It is usually called "black" or "char." Primarily, it removes color from the sugar solutions, but, as will be shown later, organic and inorganic impurities are removed as well. The ratio of bone-black used to sugar melted varies widely for different refineries, but the best practice requires at least 1 lb. of bone-black burned for each pound of raw-sugar melted.

The following are the various steps in the cycle of operations, considering any one filter: Filling the filter with char; covering the char with liquor; running the liquor or the filtration proper; washing the liquor out of the char with hot water; and the revivification of the char.

Filling the Filter with Char.—The time of filling is dependent upon the speed with which the char may be drawn from the kilns. The draw of char is controlled by means of a cam arrangement operating small doors at the bottom of the retorts. The fastest possible draw is that at which proper burning of the char can just be maintained. The distribution of the bone-black in the filter is of primary importance. If the dust and larger grains of char are not evenly distributed throughout the filter, the liquor will flow through the coarser particles, forming channels and causing many difficulties during the washing-off period. Even distribution may be obtained in many ways and there are several patented devices designed to secure this result. The char may be delivered into the filter by means of a funnel with a slightly bent stem, the funnel being turned at intervals by hand or continuously by a motor. An effective method of filling in the char is to deliver it into the filter promiscuously and have a man enter the cistern from time to time and distribute the material with a shovel. After the filter has received sufficient char, this is drawn up into a cone in the middle.

"Covering" the Bone-black with Liquor.— Air-pockets in the char must be avoided. To prevent these, the liquor is delivered slowly at the base of the cone of char, with the head of the filter off. The liquor runs down the sides of the filter until it reaches the blanket, then flows across the whole width of the filter at the bottom and rises, forcing the air

out through the cone of char, which is kept dry throughout
the covering.   When the liquor begins to flow from the
goose-neck the outlet-valve is closed and liquor is run in
until the filter is filled.   The head is now put on the
filter and the liquor is turned into it under pressure
(15–25 feet head).   The covering usually requires about four
hours.

Considerable heat is generated when hot liquor is first run
on to well-burned char.   With the char at a temperature of
140° to 150° and the liquor at 165°, the outflow during the
first few hours of running will normally have a temperature
of 185° to 190°.   If covering is stopped under these condi-
tions, or if filtration is suspended during the early stages,
the temperature in the filter may rise to such a point that the
liquor will be scorched.   The char should be cooled to at
most 150° before it enters the filters, and every precaution
should be observed to avoid interruptions to the flow of liquor
during the covering period and until the temperature of the
outflowing liquor is practically that of the liquor entering
the filter.

The Filtration.—The washed-sugar liquor from the bag-
filters (99° purity) is run on the filter at 160° F. for twenty-
four hours or longer at a rate of about 150 cubic feet per
hour.   This is followed by dark-colored sirups from gran-
ulated strikes (90° purity) and this in turn by low-grade
sugar-liquors, bag-filtered raw-sugar washings, sirup from
remelt strikes or any other low-grade material which it is
advantageous to filter.   Each successive grade is of lower
purity and in general the speed of flow is reduced and the
temperature raised with each reduction of purity.   Each
grade of liquor follows the preceding one without a break in
the filtration.

In the soft-sugar refineries, where low-purity liquors of
fine color are essential, all the liquors which are not used to
produce granulated sugar are double or triple filtered.   The
lower-grade liquors from one set of char-filters will follow the
washed-sugar liquor on a succeeding set and the darker
runnings from this set will in turn be carried on the third set.
The second and third re-filtration removes color, but does
not materially raise the purity of the liquors.

Washing Off.—At the end of the filtration period the bone-black, so far as regards color removal and absorption of impurities, is practically exhausted. The inlet-valve is now closed and the level of the liquor in the filter is lowered by gravity or air-pressure to that of the char. The head of the filter is removed and the char is leveled and then boiling-hot water is run upon it until the filter is filled. The head is replaced and hot water is run into the filter under pressure. The rate of flow of the water is about half that used for the liquor. The attempt is made to have the water displace the liquor remaining in the filter and with as little mixing of the two as is possible. This is so well accomplished in a well-running filter that there is no appreciable break in the density of the outflowing liquor for eight to ten hours after water is put on the char. When the dilute liquor has a density of about 35° Brix it is termed "char sweet-water," and the rate of flow is now further reduced and the filtrate is sent to the multiple-effect evaporator for concentration with other sweet-waters. The density and purity of the sweet-water fall rapidly. After two or three hours the water no longer contains enough sugar and is of too low purity to warrant its evaporation and it is turned to waste.

The combined concentrated sweet-waters may be sent through the process of defecation and char filtration mixed with the raw-sugar washings. The char sweet-waters are sometimes concentrated separately and are then boiled directly into low-grade strikes of sugar, in order to remove their impurities from the process as rapidly as possible.

The washing to waste is continued for at least eight to ten hours. Slow running for a longer period will give more effective washing and is the practice when time admits. Much of the organic matter is so strongly held by the char that no amount of washing will remove it. At the completion of the washing-period the water is driven out of the char by compressed-air. The bottom doors of the filter are then opened and the char is discharged into the driers.

Revivification of the Char.—The revivification of the char is accomplished by heating it in special kilns.

The wet char is passed by gravity through driers preliminary to the revivification. The driers are of various designs

and in general consist essentially of a casing through which the waste gases from the kilns are drawn. Deflecting-plates conduct the wet char slowly over the surface of this casing. The char enters the driers carrying about 20 per cent of moisture and leaves them with about 3 per cent.

The kilns consists of a furnace fired at both ends and flanked by double or triple rows of pipe-retorts through which the char slow'y passes. The retorts are of cast iron, of oval cross-section 3 inches by 9 inches or 3 inches by 12 inches and 10 to 12 feet long. The retorts are heated to a dull red heat during the revivification.

The reburning of the black decomposes some carbonates to oxides and carbonizes the organic matter which the washing failed to remove. This carbon remains in the pores of the black, and since it has no decolorizing power such as is possessed by the constituent carbon, it merely clogs the pores of the char and decreases its filtering value proportionately. The Weinrich decarbonizer, designed to remove this added carbon, is a revolving drum, slightly inclined to the horizontal, with a carefully regulated fire under it. The vegetable carbon is burned away as the char passes through the drum, thus increasing the porosity and prolonging the life of the bone-black.

The char is dropped from the retorts of the kiln, through cooling-pipes, upon belt-conveyors, and is carried by these and elevators to the filters. If necessary the char is further cooled on its way to the filters by passing it over pipes through which cold water is circulated. The bone-black is screened to remove the finer particles and the dust before it is again filled into the filter.

New char is added from time to time to compensate for the loss in screening. The char gradually deteriorates, as is shown in the next paragraph. A refinery usually renews all of its bone-black in the course of every two or three years. The dust is used in making phosphoric acid for use in the defecation or is sold for fertilizer manufacture.

The Composition of Bone-black and Its Alteration by Use.— Analyses of new bone-black of American manufacture and of the same black after several months of use, are here given:

	New Black.	After six months' use.
Carbon.....................	9.51	10.80
Insoluble silica...............	.59	.57
Calcium sulphate.............	.16	.55
Calcium sulphide.............	.06	.24
Calcium carbonate...........	8.92	4.48
Iron.......................	.06	.23
Undetermined...............	80.70	83.13
	100	100
Weight per cubic foot, loose....	43.8 lbs.	54.5 lbs·
Weight per cubic foot, packed...	48.5	59.1
Percentage between 16 and 30 mesh sieves................	84.8	

Bone-black always contains some nitrogen, which is apparently essential to its decolorizing properties. The rôle this plays in the filtration has not been determined. New black contains a considerable amount of ammonia salts, which must be removed, since they would have a detrimental effect upon the color of the filtered liquors. For this reason, new char must be throughly washed and burned before use for filtration.

As is shown by the analyses, the composition of char alters with use. The carbon increases steadily because of the deposition of vegetable carbon in the pores during the revivification. The calcium sulphate increases by the removal of sulphates from the liquors and the water. The sulphide tends to increase as the sulphates increase, due to the reduction of the latter by the organic matter during the burning. The calcium carbonate drops sharply during the first few washings and burnings and finally tends to reach a balance around 5 per cent. The iron increases slowly. Of all these impurities the calcium sulphide and iron are the most objectionable. Appreciable quantities of these two constituents will give a greenish color to the filtered liquors and a gray cast to the sugars boiled from them. A bone-black may become

unfit for use if the calcium sulphide content exceeds 0.4 per cent. Thorough washing and burning, together with the constant addition of new black, will prevent the sulphide content from becoming abnormal.

Action of Bone-black on Sugar Solutions.—Bone-black not only removes color from the sugar solutions, but also absorbs organic and inorganic impurities. The black is selective in its action, certain classes of material being retained by it more strongly than others. Solutions containing color due to overheating (caramel) are not easily decolorized. Gums and albumen are strongly held by the char and no amount of washing will completely remove them. Of the salts, the carbonates, sulphates and phosphates are readily absorbed, while the chlorides and nitrates are not absorbed to any great extent. Invert-sugar or "glucose" is absorbed to a much greater extent than sucrose, but is largely washed out again with the hot water. Consequently the glucose ratio of the filtered liquors is lower than that of the unfiltered, while the ratio of the diluted runnings and sweet-waters is very much higher. The combined onflow compared with the combined filtrate shows practically a glucose balance. This presupposes a correct control and well-burned char. With acid-liquors or insufficiently burned char, heavy losses by inversion may occur in the filters.

In actual refinery practice, the bone-black will absorb from 80 to 85 per cent of the color, from 30 to 40 per cent of the mineral matter or "ash," and from 50 to 60 per cent of the organic non-sugars of the combined onflowing liquors.

54. Crystallization of the Sugar.—*Classification of the Liquors.*—The liquors are classified at the filter outlet-pipes according to their purity and color and are distributed to storage-tanks near the vacuum-pans. In the continuous system of filtration, in which no two filters are at the same phase of their cycles, all grades of liquors are flowing at the same time. The liquors are classified about as follows: First liquor: Filtered washed-sugar liquor, "water white" and of 99° to 99.5° purity; second liquor: Filtered granulated-sirups, off-white or slightly yellow and of 90 to 93° purity; third liquor: Filtered or double-filtered washings or low-grade meltings, golden yellow and of 84° to 87° purity; fourth

liquor: Last runnings, too dark to make granulated sugar and of 75 to 80° purity.

Where the "set" system of filtration is in use, all the filters of a set are delivering the same kind of liquor at the same time and there is not the necessity for a rigid classification.   The distribution on the pan-floor is made to suit the needs of the boiling-system.

Boiling to Grain.—The vacuum-pans used in refining do not differ from those of the raw-sugar factory.   The general principle of the manipulations is the same in the two branches of the industry,[1] but from the nature of the product, greater care must be exercised in the refinery.   This is due to the necessity of boiling sugars to certain specifications as regards the size and hardness of the crystals.   The raw-sugar factory usually aims only to make sugars of a uniform size and hardness of grain.   In boiling granulated and other hard sugars, a high pan-temperature is maintained (180°), while for soft sugars, in which a small spongy grain is desired, low temperatures (120°-130°) prevail.

When hard sugars only are to be made, a fixed system of boiling may be adhered to.   The first liquor is boiled for the fancy grades, cubes, cut loaf, confectioners' sugars, etc. The sirups purged from these strikes are boiled back with more liquor to make the ordinary granulated.   The boiling-back is continued until the sirups, usually of about 90° purity, are of such color that they are no longer suitable for reboiling.   These sirups are now returned to the bone-black and are refiltered.   The second liquor and the third liquor are boiled to make "off-granulated" sugar. This is a slightly "off-color" sugar which is disposed of by gradually and slowly mixing it with the better grade of granulated strikes.

The sirups from the off-granulated strikes are boiled with fourth liquor for "high remelt" strikes of 75° to 80° purity. The sugars of these strikes are washed to a high test (98° purity) and are melted directly with the washed raw sugar. The sirups from these strikes are boiled back on a footing of fourth liquor to make strikes of about 67° purity.   These

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[1] See page 90, relative to sugar-boiling in the raw-sugar factory.

magmas are discharged into crystallizers where they are kept
in motion during two to three days. They are then purged
without the use of wash-water and yield a sugar of from 85°
to 90° purity. This sugar may be mixed with high-test raws
and washed with them, or, preferably it may be melted
directly with other low-grade raws and be submitted to the
processes already described.

The sirups purged from these low-grade remelt strikes
form the residual sirup or "barrel syrup" of the refiners.

The procedure in a soft-sugar refinery in boiling the high
liquors to granulated sugar is much the same as that already
described. The soft sugars are graded according to color,
varying from an almost pure white to a deep brown sugar.
The lower grades of liquors from a set of char-filters are boiled
into a series of strikes of successively lower purity, which
are planned to yield sugars of the desired colors. The sirups
from soft-sugar strikes are either boiled back directly or are
first char-filtered, as the needs require. The varying demand
for the different grades necessarily precludes the possibility
of a fixed boiling-system. It is frequently necessary to boil
sugars for "remelt," as in the hard-sugar houses. At times
the output of soft sugars may be so large that but a very
small percentage of the impurities is turned out as barrel-
sirup.

55. Drying and Finishing the Product.—The separa-
tion of the crystals from the sirup in the magmas is effected by
centrifugal machines such as are used in the factories (**42**).
The white sugars are very thoroughly washed in the machine
to remove all adhering sirup. The moist sugars are con-
veyed from the centrifugals to distributing-bins above the
granulators.

The bulk of the white sugar is sent through the granulators
for drying. The granulator also separates the crystals from
one another, hence its name.

The granulator is an iron drum (Fig. 17) about 6 feet in
diameter and 20 feet long, slightly inclined to the horizontal
toward the discharge end, and revolving on trunnions. A
series of narrow shelves attached to the inside of the drum,
longitudinally, serves to lift the sugar and let it fall through
heated air as the drum revolves. The air is heated either by

means of a steam-drum extending through the middle of the granulator or by a large group of steam-pipes at the discharge end of the drum. The air is drawn over the pipes and through the granulator by an exhaust fan. The fan also removes the sugar-dust. The illustration (Fig. 17) is of a Hersey granulator, the usual American type.

Two granulator-drums are usually operated in series, one above the other. The upper is fitted with a heater and the lower with a central steam drum. The sugar leaves the upper-drum partly dried and quite hot, hence very little steam is required to complete the drying in the lower section. The sugar should leave the lower drum comparatively cool, preferably below 110°. It is sometimes necessary to make special provision for cooling the sugar. If sugar is packed
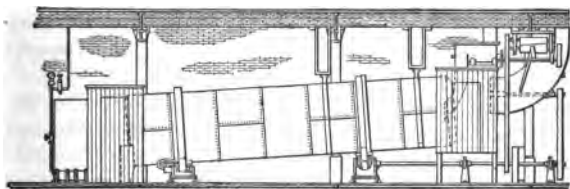
Fig. 17.

while hot it is very liable to cake in the packages. The sugar falls from the granulator to a set of screens which classify it according to the size of the crystals, remove the lumps and coarser dust, and deliver the products into the packing-bins. The screened sugar is packed in barrels, bags and such other containers as the market requires. Barrels rest upon "shakers" while filling. Certain refineries are equipped with large storage-bins which permit the packing of sugars during the day-time only.

Automatic machines are used in filling, weighing and closing small packages. Cubes and cut loaf-sugars are packed in cartons. The European practice of wrapping two or three cubes or "dominoes" in moisture-proof paper, for restaurant service, has been introduced into the United States.

The various kinds of lump- or loaf-sugars are all made by mixing sugar of the proper grain with a heavy pure sugar-

sirup to form a magma. This magma is variously treated, by pressing, molding or in special centrifugals, to form cubes directly or slabs and bars. These are usually dried in hot closets. The cubes are ready for packing after they have been dried. The slabs and bars are cut or sawed to form cut and sawed loaf-sugar. These are broken down in making crushed loaf-sugar.

Powdered or pulverized sugars of various degrees of fine-ness are made by grinding coarse granulated in a mill and passing it through bolting-cloth.

Brilliant or candy "A" is a large grain sugar which is barreled while moist, just as it leaves the centrifugal-machine. Confectioners' "A" is a smaller grain-sugar packed in the same way.

The soft sugars, white and yellow, have already been described. These sugars are packed while moist, directly from the centrifugals. The soft sugars are classified accord-ing to a series of arbitrary trade color-standards.

Granulated sugar now forms a large part of the output of a refinery and the total product of the smaller establish-ments. This grade is classified according to the size of the crystals as extra coarse, coarse, fine and extra fine granulated. The ordinary commercial granulated is the fine grade. Fruit granulated is the finer screenings from fine-grained sugar. As has been explained in an early chapter of this work, the size of the grain is determined in the pan-boiling.

56. "Barrel Syrup."—The sirups purged from low-grade remelt strikes form the residual sirup which is usually packed in barrels for the market. As a rule the sirup is diluted to 55° Brix and reboiled "smooth" before barreling. Certain refineries pay especial attention to this sirup and char-filter it to improve the color before reboiling.

This sirup varies in composition through rather wide limits, depending on the class of sugar from which it is de-rived and upon other factors. A typical analysis would be as follows: Polarization 34 per cent; reducing sugars 22 per cent; ash 6 per cent; water 22 per cent; organic non-sugar 16 per cent.

57. Yield of Refined Sugar.—The yield of sugar in a refinery is expressed in percentage terms of the raw

sugar melted. The following figures are illustrative: Polarization of the melt, 95°; granulated yield, 92.3 per cent; sirup yield, 5 per cent at 34° polarization (1.7 per cent of sucrose per cent of melt). Sucrose lost in manufacture, 1 per cent. If other sugars than granulated are made they are calculated to a basis of granulated sugar and sirup.

REFINERY TECHNICAL AND CHEMICAL CONTROL

58. Introductory.—The technical control of a refinery is simpler than that of a raw-sugar factory. The weighing and analysis of the raw material entering the refinery offer no difficulty. All the control figures are computed upon the basis of the weight of raws. A technical statement may be made up of comparatively few figures—the analysis and weight of the raw sugar melted; the analyses and weights of the refined sugars and sirup produced; the stock-in-process figures for the beginning and end of the period.

Technical Statement.—Each package of raw sugar is weighed and sampled as it is dumped and the samples are polarized at convenient intervals, usually twice daily. Complete analyses are made weekly, or as often as desired, of a weighted sample made up from the daily melts. Besides the average polarization, which is computed from the component polarizations, the invert sugar, moisture, ash and organic nonsugars are determined by the usual methods cf sugar analysis. The analysis of the melt of the technical period is computed from these analyses and the weights of material which they represent.

The refined sugar is weighed immediately after packing. No analysis of the granulated sugar is made and its polarization is always taken as 100°.[1] Soft sugars are weighed,

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[1] This practice is equivalent to correcting the apparent polarization of the sugar for temperature error. Laboratory temperatures are usually above 20° C., and where such is the case, the assumption of the number 100 for the product, and not correcting the polarization of the raw material, results in an apparently lower loss of sucrose than actually occurs.

In fact, the correction of both the polarization of the raw material and that of the product would not result in correct loss figures, since the direct polarization of the raw sugar is below the true or Clerget number. It is probable that a scientifically accurate deduction of the

sampled and analyzed, as in the case of raw sugars, and a weighted average analysis is calculated for the period.

The barrel-sirup is sampled and measured by lots and the density and polarization of each is determined. Weekly complete analyses are made of a composite sample and a weighted average analysis for the technical period is computed. At the end of every period—usually the technical periods include four weeks—an inventory of the material in process is made. All material containing sugar is measured and sampled. The density and purity of the samples are determined. The pounds of solids are computed from the volume of the material in cubic feet and the pounds solids per cubic foot, as indicated by the density. The solids multiplied by the purity give the sucrose. The solids less the sucrose give the solid impurities. In this way the total solids, total sucrose and total impurities in the stock are ascertained. To compute these figures to available sirup and available granulated sugar, it may be assumed that all the impurities will go to make sirup of the same composition as that produced during the period.

Then:

$$\frac{\text{Lbs. solid impurities in stock} \times 100}{\text{Per cent solid impurities in sirup produced}}$$

$$= \text{lbs. available sirup in stock;} \quad (1)$$

loss figure would not be of more practical value to the refinery, as such, than the number as now customarily determined. This refers to a refinery having no exceptional temperature conditions. The complications and expense of securing scientifically accurate data are prohibitive.

It is not clear, however, that a closer approximation to true figures would not be desirable in locations of excessive and irregular heat. This condition would necessitate either a control of the laboratory temperature or corrections of a more or less arbitrary nature. Dr. C. A. Browne (Handbook of Sugar Analysis, p. 260) has shown that corrections may only be properly applied to cane-sugars polarising above 96° and to beet-sugars.

The technical statements of the refinery are designed to give comparative control figures and where temperature fluctuations are not excessive they accomplish this very successfully. Under average temperature conditions, one report is comparable with its predecessors. (G. L. S.)

Lbs. available sirup in stock $\times$ polarization of sirup produced

$$\frac{}{100}$$

$$= \text{lbs. sucrose in sirup in stock.} \quad (2)$$

Total sucrose in stock $-$ sucrose in sirup in stock $=$ lbs. available granulated in stock.

Example:

Assume a stock in process of 1,180,000 lbs. solids

850,000 lbs. sucrose

330,000 lbs. solid impurities.

Assume a barrel-sirup produced as containing:

Sucrose................................... 34.2%

Water.................................... 22.1%

Solid impurities (ash, glucose, organic)........ 43.7%

_____

100

$$\frac{330,000 \times 100}{43.7} = 778,032 \text{ lbs. available sirup;} \quad (1)$$

$$\frac{778,032 \times 34.2}{100} = 258,261 \text{ lbs. sucrose in sirup in stock;} \quad (2)$$

$850,000 - 258,261 = 591,739$ lbs. available granulated in stock.

The increase or decrease in the available granulated in stock in process at the end of the period as compared to that at the beginning is added to or subtracted from the actual production of granulated for the period; the same calculation is made with regard to the sirup produced and the sirup in stock. These are *net* productions of sugar and sirup for the period.

These net weights produced are each divided by the weight of raws melted to give the net productions per cent melt. The analyses of the granulated, the soft sugars and sirup are calculated to per cents of the melt by multiplying each constituent of the analysis of each of these three products by the percentages of the product in terms of the melt. The various constituents of these analyses per cent of the

melt can be totaled to give the analysis of the combined output of the refinery in terms of the melt. A comparison of this analysis with that of the melt itself gives the increase or decrease of each constituent during the process of refining.

To illustrate this, let us assume a set of net yields for a refinery period and calculate the loss in sucrose for the period:

Polarization of the melt....94.9°
Net yield of granulated....84.3%
Soft sugars produced...... 8.9% at 88.8° polarization
Net sirup production...... 4.5% at 34.1° polarization

Then,

Sucrose in melt........................   94.90

$$\text{Sucrose in granulated } \% \text{ melt} = \frac{84.3 \times 100}{100} = 84.30$$

$$\text{Sucrose in soft sugars } \% \text{ melt} = \frac{8.9 \times 88.8}{100} = 7.90$$

$$\text{Sucrose in sirup } \% \text{ melt} = \frac{4.5 \times 34.1}{100} = 1.53$$

Sucrose in total product % melt..........   93.73

Sucrose lost in refining % melt.............   1.17

Following this same method of calculation, the gain or loss of invert-sugar, ash, water and organic non-sugar· may be traced.

Routine Control.—The routine control of the refinery depends largely upon determinations of the purity of the materials in the successive steps of the process. The char-filter and pan-work are entirely controlled on a basis of purity. The number of these purity tests required day and night is so large that the work is usually conducted in a separate laboratory, on or near the vacuum-pan floor, by boys trained to do only this testing. This leaves the chemists free to do the analytical work involved in the technical control.

'The dilute purity method of Casamajor is used in this work. The material—liquor, magma or sirup—is diluted to any convenient density, usually between 15° and 20° Brix, and the corrected Brix is determined. A part of the solution is clarified with Horne's dry subacetate of lead, if such preparation is necessary, and after filtration it is polarized directly. The polariscope reading multiplied by the factor corresponding to the degree Brix gives the purity coefficient. The factors are computed from the formula Factor $= \dfrac{26.048}{\text{Sp. gr.} \times \text{degree Brix}}$. The figuring is simplified by the use of Horne's table of purities for use in refinery control, given on page 526.

59. Special Analytical Methods.—*Black Paste.*—A

convenient routine method for determining the available phosphoric acid (P_2O_5) in monocalcic phosphate-paste is as follows: Wash 10 grams of the paste into a 200-cc. flask with distilled water, breaking up the lumps with a rod. Make up to the mark, mix thoroughly by shaking and filter. Titrate 20 cc. of the filtrate (1 gram of the paste) with tenth-normal alkali, using methyl-orange as the indicator. This gives the acidity due to uncombined hydrochloric acid. The number of cc. of N/10 alkali, with methyl-orange indicator $\times 0.365 =$ per cent free hydrochloric acid (HCl).

Titrate a second 20-cc. portion of the filtrate, using phenolphthalein indicator. This titration gives the total acidity due to the acid phosphates and the free acid. The calculations are made as follows: Number of cc. N/10 alkali with phenolphthalein indicator $-$ cc. N/10 alkali, methyl-orange indicator $\times 0.35 =$ per cent available phosphoric acid (P_2O_5).

Bone-black: Preparation of the Sample.—After thoroughly mixing the sample reduce it to 200–300 grams by subsampling. Pass a magnet through a thin layer of the sample to remove particles of iron that may have gotten into it from the retorts and filters. Grind about 100 grams of this prepared char in a porcelain mortar to a powder, all of which should pass through a 100-mesh sieve. The ground sample must be kept in a tightly stoppered bottle to prevent absorption of moisture.

Bone-black: Moisture Determination.—Heat 5 grams of the unground portion of the subsample during four hours at 110° C.

Bone-black: Carbon and Insoluble Matter.—Treat 2 grams of the ground char with 10 cc. of concentrated hydrochloric acid and 50 cc. of water. Boil gently for fifteen minutes, filter through a tared Gooch crucible and wash the residue with water to the disappearance of chlorides. Dry the crucible and contents at 100° C. and weigh; ignite to constant weight over the flame of a lamp.

Loss on ignition ÷ 2 × 100 = per cent carbon;
Residue after ignition ÷ 2 × 100 = per cent insoluble matter.

Bone-black: Determination of Calcium Sulphate.—To 25 grams of the powdered char, in a 250-cc. flask, add 25 cc. water and 100 cc. concentrated hydrochloric acid, gradually. Boil fifteen minutes. Add about 100 cc. water, and after cooling to room temperature, dilute to the mark with water, mix and filter. Evaporate 200 cc. (= 20 grams of char) of the filtrate to about 150 cc. Proceed with the analysis as is described in page 362, using the concentrated solution obtained as above. The barium sulphate precipitate should be first washed by decantation. Calculation: Weight barium sulphate ÷ 20 × .5833 × 100 = per cent calcium-sulphate ($CaSO_4$).

Bone-black: Determination of Calcium Sulphide.—To 25 grams of the powdered char in a 250-cc. flask add 0.5 gram of potassium chlorate, then 25 cc. of boiling water and follow this with 100 cc. concentrated hydrochloric acid, *added very slowly.* Proceed as in the determination of calcium sulphate, described above. Great care must be exercised in adding the acid, very slowly at first, in order that no sulphur be lost as hydrogen sulphide (H_2S). The barium sulphate obtained in this analysis corresponds to the sum of the sulphide and sulphate in the char. Subtracting that already found for the calcium-sulphate leaves the barium-sulphate equivalent to the calcium sulphide. Calculation: (Total barium sulphate—barium sulphate derived from the calcium sulphate) ÷ 20 × .3091 × 100 = per cent calcium sulphide (CaS).

Bone-black: Volumetric Determination of the Iron.[1]—The following reagents are required:

(1) Standard potassium permanganate: Dissolve 4 to 5 grams of the salt in 1000 cc. of water. Check this solution against an iron solution of known strength, prepared as follows: Dissolve 2.5 grams of piano-wire, or of the grade of iron wire that is prepared especially for standardizing, in a small quantity of hydrochloric acid, and dilute this solution to 250 cc. in a graduated flask. Use 50-cc. portions of this solution under the conditions of the analysis, as below, in standardizing the permanganate.

(2) Phosphoric acid and manganous solution: Dissolve 50 grams of manganous sulphate crystals in about 250 cc. of water, with the addition of a few drops of sulphuric acid; add 250 cc. of phosphoric acid solution of 1.3 specific gravity, followed in order by 150 cc. of water and 100 cc. of concentrated sulphuric acid. The phosphoric solution may be prepared from the 85 per cent acid (H_3PO_4).

(3) Stannous chloride solution: Dissolve 30 grams of pure granulated tin in 125 cc. of concentrated hydrochloric acid, with heating. Solution is promoted by the addition of a few pieces of platinum foil. Dilute the solution with 250 cc. of water and filter it through asbestos. Add 250 cc. of concentrated hydrochloric acid and 500 cc. of water to the filtrate.

(4) Mercuric chloride solution: Dissolve 50 grams of the salt in 1000 cc. of water.

Proceed with the analysis as follows: Ignite 10 grams of the powdered bone-black and digest the residue with 30 cc. of concentrated hydrochloric acid, with gentle boiling during fifteen minutes. Filter the solution through a Gooch crucible and wash the residue thoroughly with small quantities of hot water. Heat the filtrate, contained in a large Erlenmeyer flask, to nearly boiling and add the stannous chloride solution to it drop by drop until the yellow color disappears. Add 60 cc. of the mercuric chloride solution, all at once, and mix well by shaking the flask; add 60 cc. of the phosphoric acid and manganous solution and 600 cc. of water.

[1] Adapted from Clowes and Coleman's "Quantitative Analysis," 5th ed., p. 206.

The titration of the material prepared as above may be conducted in the flask placed over a white background or the solution may be transferred to a large porcelain dish. The flask, in the latter case, should be thoroughly washed and the washings added to the solution in the dish. Add the standard permanganate solution from a burette, with constant stirring, until the liquor assumes a faint pink color, which should disappear after three or four minutes' standing.

Make a similar titration of the solution prepared with the iron wire to ascertain the iron value of the permanganate solution. The percentage of iron in the char may be readily calculated from the data obtained in the two titrations.

Bone-black: Calcium Carbonate and Phosphates. — The calcium carbonate may be determined by the methods on page 389. This determination is of less importance than prior to the invention of the mingling process (**50**), when it was necessary to filter highly alkaline beet-sugar solutions.

The percentage of phosphoric acid is of no particular significance, except the spent char is to be sold on a basis of its fertilizing value. In this event, the customary methods of agricultural analysis are used.

Bone-black: Thoroughness of the Revivification.—The test of the efficiency of the revivification is of very great value in the control of the kilns. Tests are made at very frequent intervals throughout the day.

To a measured volume of char add an equal volume of sodium hydroxide solution of 9° Brix. Heat the mixture in a boiling salt-water bath for two minutes. A properly burned char will impart no color to the soda solution. A yellow or a brown color indicates a poor revivification (under-burning), the depth of the color being directly in proportion to the amount of organic matter remaining in the black. An excess of sulphides will give a greenish cast to the solution.

Overburning occurs when the char is heated so hot that a part of its lime is converted into the oxide. Should the caustic soda solution remain uncolored in the test described above, a sample of the char should be shaken with distilled water and a drop of phenolphthalein solution added to it. Overburning is indicated by the solution turning red, due to

calcium oxide. Should the color be but a pink, the test does not show an objectionable condition. Overburning is not so grave a fault as underburning.

Bone-black: Weight per Cubic Foot.— Both the "loose" and "packed" weights are required. These weights are calculated from the apparent specific gravity of the char under the two conditions.

Loose weight: Fill a tared 500-cc. flask loosely with char. The flask should not be shaken or tapped during filling. The weight of this char divided by that of an equal volume of water gives the apparent specific gravity of the sample. Calculate the weight as below.

Packed weight: Proceed as before except that the flask should be shaken and tapped constantly while filling. Multiply the apparent specific gravities by 62.5 to ascertain the weights of a cubic foot of the char.

Bone-black: Decolorizing Power.—By far the best test of a bone-black is its performance in actual use. Tests should be made on a large or manufacturing scale when this is practicable. Laboratory filtrations for comparing the decolorizing and absorptive powers of chars may be carried out in cylindrical copper funnels of convenient dimensions, *e.g.*, 4 inches in diameter by 15 inches high. Each funnel should be provided with a small cock at the bottom. The char should rest upon a plug of absorbent cotton to keep the filtrate clear of the black. The funnels or filters should be immersed in a water-bath, provided with suitable openings for the outlet-cocks, and should be filled to within a few inches of the top with the chars to be compared. The weight of the char should be the same in each of the filters.

A suitable solution for comparisons is prepared by dissolving a molasses-sugar to form a liquor of about 55° Brix and defecating it with lime and phosphoric acid as in the refinery. This liquor should be heated to about 165° F. and equal portions of it should be added to each filter, little by little, or as under service conditions, to avoid forming air-pockets. After covering the char, the remainder of the liquor may be poured into the filter. Maintain the temperature of the water-bath at 160°–170° for several hours and then draw off the filtered liquor from the outlet-cocks. Compare

the colors of the filtrates and unfiltered liquor and make complete analyses of each. The percentage absorption of color, ash and organic non-sugars, as well as the improvement in purity and the change in the glucose ratios may now be calculated for each char, using the constituents of the unfiltered liquor as a basis. A supply of a good grade of bone-black should be kept as a standard of comparison, if many such tests are to be made.

It is essential in all tests of this character that all the conditions of the experiment shall be identical for all the samples of black to be compared. Certain points of the procedure must necessarily be arbitrary and the conditions can best be chosen to suit the particular requirements of the experiment. In so far as is possible, factory conditions as regards temperature, ratio of char to sugar, density of the liquor, etc., should be maintained.

The decolorizing power of bone-black is determined by means of a colorimeter. Stammer's instrument for this purpose is a very convenient form, and the results obtained by different operators are comparable. This instrument consists essentially of an arrangement for comparing the depth of color of a column of sugar solution with standard colored-glass plates. An eye-piece is so arranged that the color of the solution under examination appears upon one half of a disk, and that of the standard glass on the other. The eye-piece and a tube containing the glasses are raised and lowered by means of a rack and pinion, the length of the column of solution being varied at the same time; this length is shown on a scale by means of a pointer carried by a slide. The theory of this instrument depends upon the variations in the intensity of the color of the solution, proportionate to the length of its column. In using the colorimeter the object is to equalize the intensities of the colors as seen on the disk through the eye-piece, by lengthening or shortening the column of the solution under examination. The strength of solution being known, a comparative statement of depth of color in terms of the sucrose present may be made, or the reading on the scale may easily be reduced to an expression showing the depth of color as compared with the standard.

This instrument may be used in determining the **decolorizing** power of a char in the following manner:

A standard-color solution should be prepared with caramel, a definite quantity being used. Duboscq recommends 2 grams per liter for his instrument. Prepare the caramel by heating pure cane-sugar to about 215° C., until all of it is decomposed. In examining bone-black, determine the depth of color in the standard solution, then heat a measured volume of this solution with a weighed portion of the char a certain length of time, for example, half an hour, filter, and again determine the intensity of color. The difference in the depth of color, referred to the standard, represents the efficiency of the bone-black in decolorizing. In sugar-house work a standard bone-black of a known decolorizing capacity is convenient for comparison. Comparable results can only be obtained by adopting certain conditions and adhering to them in all experiments.

The decolorizing power may be roughly determined, in the absence of a colorimeter, as follows: Treat a measured volume of a standard-color solution as described above. Fill a cylinder, similar to those used in Nesslerizing, to a certain depth with the decolorized and filtered solution; take the same volume of the standard solution in a similar cylinder, and add water to this latter from a burette until a portion of the same depth as that of the decolorized solution shows the same intensity of color when examined over a white background. The volume of water added is inversely proportional to the decolorizing power of the char.

SUGAR ANALYSIS.

CHEMICAL CONTROL OF THE FACTORY.

60. Sugars.—In the manufacture of sugar from cane
the sugars of importance in the analytical work are sucrose,
dextrose, and levulose.

Sucrose, or cane-sugar, is the most important of these.
Dextrose and levulose, and possibly other reducing-sugars,
usually grouped with them by cane-sugar chemists under
the name "glucose," are of importance on account of their
influence in analytical and manufacturing processes. The
sugars are classed chemically as carbohydrates. A table
showing the more important chemical and physical properties
of the carbohydrates is given on page 458. A few of the
properties of those sugars which immediately concern the
chemist of a cane-sugar factory, are given in the following
paragraphs.

**61. Sucrose, Saccharose, Saccharon, or Cane-
sugar.**—This sugar is very widely distributed in the vegetable
kingdom and in its pure state is the refined sugar of commerce.
In a classification of the sugars it belongs to the disaccharides,
derivatives of hexoses, and its formula is $C_{12}H_{22}O_{11}$. The
commercial sources of cane-sugar are the sugar-cane, the
sugar-beet, the maple-tree, and certain palms. The sorghum-
cane is often very rich in sucrose, rivaling the tropical cane,
but the manufacture of sugar from this plant has not
been a commercial success, though very large quantities of
table-sirup are annually made from it, in nearly all parts
of the United States.

Sucrose crystallizes in the monoclinic system, forming
hemihedral anhydrous transparent crystals. The specific

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gravity of the crystals at $\frac{17\frac{1}{2}°}{17\frac{1}{2}°}$ C. is 1.58046 (Gerlach). Sucrose is readily soluble in water and in diluted alcohol. It is practically insoluble in absolute alcohol, ether, chloroform and anhydrous glycerine.

Dry sucrose, free of raffinose or other impurity, may be heated to a temperature of 120°–125° C. without browning; it melts at a temperature of 160° C. Moist sucrose decomposes at temperatures above 100° C. The action of acids and salts on sucrose is given in 84.

Sucrose is not directly fermentable, but is converted by many ferments into invert sugar. The invert sugar promptly ferments. Further information in regard to fermentation is given on page 409.

Sucrose in common with many other substances has the property of rotating the plane of polarization of a ray of light. It rotates the plane to the right and is termed dextrorotatory. This property is utilized, as will be shown (see 67), in the construction of polariscopic apparatus for the analysis of sugars.

62. Dextrose.—This sugar is also widely distributed in the vegetable kingdom, where it is found in mixtures with other sugars. Its chemical formula is $C_6H_{12}O_6$ and it belongs to the monosaccharides, hexoses. Dextrose is always present in sugar-cane, and on inverting sucrose, it and levulose are formed in equal quantities.

Anhydrous dextrose forms rhombic crystals whose melting point is 144°–146° C., and the hydrate forms crusts or transparent crystals which melt at 80°–90° C.

Dextrose is readily soluble in water and in alcohol, the solubility in the latter varying with its dilution and temperature. It rotates the plane of polarization of light to the right.

The chemical methods for the detection and estimation of dextrose are based upon its property, in alkaline solution, of absorbing combined oxygen and reducing metallic oxides to lower oxides. The reaction utilized in analysis is the reduction of cupric to cuprous oxid. For other properties of dextrose, refer to the table, page 458.

63. Levulose.—This sugar is usually associated with dextrose and sucrose in sugar-cane. It is widely distributed, and is often called fructose or fruit-sugar. Levulose is a monosaccharide, hexose (keto-hexose); it forms colorless, shining, needle-shaped crystals of the rhombic system, which are hygroscopic and difficult to produce. The crystals melt at 95°-105° C. The chemical formula of levulose is $C_6H_{12}O_6$. This sugar is very soluble in water and alcohol. It rotates the plane of polarization of light to the left, and is therefore termed laevorotatory. In mature cane the quantity of levulose is small as compared with the dextrose. Both these sugars are often present only in faint traces, and occasionally the levulose is absent.

Even though levulose be absent or present in very small quantity in the juice it always appears in large proportion in defecation-process molasses. This increase of levulose is not entirely due to inversion and may occur when no sucrose has been inverted. Such molasses will often have a low direct polarization and a very high, true sucrose-number.

The reappearance or increase of levulose is due to the action of alkalis and salts of alkalis with heat upon the dextrose. A part of the dextrose is converted into levulose. Likewise under similar conditions levulose may be isomerized and converted into dextrose. There are many references to this phenomenon in the chemical and technical journals.

It is interesting to note that according to de Haan [1] the direct polarization and Clerget numbers of a carbonation cane-molasses differ but little.

64. Invert Sugar.—When sucrose is acted upon by acids and certain other reagents it is converted into a mixture of equal parts of dextrose and levulose. The sucrose is said to have been hydrolized or inverted. The mixture of sugars is called invert-sugar.

The expressions "invert-sugar," "reducing-sugars" and "glucose" are used synonymously in the cane-sugar laboratories.

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[1] Verbal communication and Archief, about 1910 or 1911.

65. Abnormal Constituents of Sugar-cane Products.[1]

—There are a large number of compounds which, while not occurring normally in the juice of the cane, yet occasionally make their appearance in the cane and its numerous products, as the result of fermentation or of destructive influences during the process of manufacture. These abnormal products may be roughly classified as follows: *first,* sugars and closely related derivatives of the same; *second,* the gums; *third,* acids; *fourth,* alcohols and esters; *fifth,* gaseous products. A few of these numerous compounds may be briefly mentioned:

1st. *Sugars and closely related derivatives of the same.*

Mannose, $C_6H_{12}O_6$, and the non-fermentable sugar-glucose $C_6H_{12}O_6$ have been reported by Pellet[2] in cane-molasses from Egypt. These two products are produced by the action of alkalies upon dextrose and levulose. They occur in cane-molasses in perceptible amounts only when an excess of lime has been used in the clarification.

Mannite $(C_6H_{14}O_6)$. This body is formed in considerable amount through the reduction of dextrose and levulose in certain fermentations of juices and sirups. Glycerol $(C_3H_8O_3)$ and Dimethylketol[3] $(C_4H_8O_2)$ have been reported in fermented molasses in small amounts.

2d. *The Gums.*

Dextran $(C_6H_{10}O_5)_n$. This gum, a most common and troublesome enemy of the sugar-maker, is the product of various fermentations, such as that produced by the Leuconostoc (Froschlaich), and is of frequent occurrence in canes injured by freezing or by insect ravages. The formation of this viscous gum in canes soon renders them worthless for milling. Its high specific rotation (+200), three times that of sucrose, introduces a serious error into the polarization of cane-products, unless the gum is

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[1] This article (**65, 66**) is included through the courtesy of Dr. Charles A. Browne, who prepared it at the author's request.

[2] Report of the 5th International Congress of Applied Chemistry, **3**, 383.

[3] Browne, La. Planter, 1905, p. 237, vol. 34.

first removed by alcohol. Hydrolysis of dextran, with acids, gives dextrose.

Levan. A gum found by Smith[1] and Steel in sugar-cane products in Australia and produced by the Bac. levani-formans. This organism was found to be very destructive in raw sugar; it causes a rapid inversion of sucrose and produces the slimy gum, levan, which has a specific rotation of -40. Hydrolysis of levan, with acids, yields levulose.

Cellulan. A gum found by Browne[2] in the tanks of a sugar-house in Louisiana. It is formed in certain fermenta-tions of cane-juice and sirup, and consists of large leathery lumps insoluble in caustic alkali (distinction from dextran). The gum on treatment with boiling alkali yields a prod-uct giving all the reactions of cellulose (solubility in cuprammonium and blue coloration with zinc-chloride and iodine), and on hydrolysis with acids is converted into dextrose.

Mannan. A gum found occasionally in the sedementary deposits of fermented juices and sirups. Hydrolysis of mannan, with acids, gives mannose.

Chitine $(C_{13}H_{30}N_2O_{12}?)$. This substance, which strictly speaking does not belong to the gums, was found by Browne[2] in large quantities in the scums of hot-room molasses in Louisiana. It is of fungoid origin and on hydrolysis with hydrochloric acid yields an amine-sugar, glucose-amine $(C_6H_{11}O_5NH_2)$.

3d. *Acids.*

Formic, acetic, propionic, butyric, capric, and various other acids of the fatty series, have all been found among the fermentation-products of cane-juices and sirups. In addi-tion to the above, lactic acid should be mentioned as of very common occurrence in juices, sirups, and molasses. The latter acid may be formed either by the action of lime upon the sugars of the juice during clarification, or through the agency of various organisms, as Oideum lactis, Bac. lacticus, etc.

[1] International Sugar Journal, 4, 430.
[2] La. Planter, 1905, p. 238, vol. 34.

Oxalic, glutaric, and other dibasic acids have also been reported as occurring in molasses in small amounts.

4th. *Alcohols and esters.*

Ethyl, amyl, butyl, and other alcohols have been found in the fermented products of the sugar-cane. The combination of these alcohols with the various acids, acetic, butyric, etc., gives rise to numerous esters, the fruity odor of which is characteristic of many fermented cane-products. Ethyl sulphite and sulphide have also been found in fermented juices which have undergone sulfitation, and the objectionable odor (tufo) of these compounds is frequently noticeable in the spirits from tropical distilleries.

5th. *Gaseous products.*

Carbonic acid (CO_2) is nearly always given off by cane-products undergoing fermentation. In many fermentations a reduction takes place and in such cases hydrogen may be evolved. The explosion of hydrogen generated from the "sour water," left standing in vacuum-pans, has occurred at times, and on one occasion with disastrous effects.[1]

Another product in the reducing fermentation of juices which have been sulfured is hydrogen sulphide (H_2S), and the odor of this gas from sulfured juice or sirup which has been left standing a long time is sometimes almost unbearable

66. Composition of Sugar-cane Molasses.—The composition of sugar-cane molasses is very variable, being dependent not only upon the composition of the cane, but also, and to a much greater degree, upon the process of manufacture. The table on p. 140, condensed from a large number of analyses made at the Louisiana Sugar Experiment Station, gives the approximate composition of third molasses. (Browne.)

The xanthin bodies of cane-molasses are probably derived from the breaking up of the nucleo-proteids of the juice during clarification. A large part of the acid bodies of molasses, as melassinic, glucinic, and saccharinic, are not present in the juice, but are formed by the action of lime upon the reducing-sugars in the clarification.

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[1] La. Planter, 1890, **5**, 243.

Water................	20.00%		20.00%
		Silica, SiO_2...............	0.50
		Potash, K_2O..............	3.50
		Lime, CaO...............	1.50
		Magnesia, MgO...........	0.10
Ash.................	8.00	Phosphoric acid, P_2O_5....	0.20
		Sulphuric acid, SO_3.......	1.60
		Chlorine, Cl..............	0.40
		Soda, iron, etc., Na_2O, Fe_2O_3, etc...................	0.20
		Sucrose.................	32.00
Sugars.............	62.00	Dextrose................	14.00
		Levulose................	16.00
		Albuminoids.............	0.30
		Amids (as asparagin).....	0.30
		Amido acids (as aspartic)..	1.70
Nitrogenous bodies...	3.00	Nitric acid..............	0.15
(Total N = 0.5%).		Ammonia................	0.02
		Xanthin bodies...........	0.30
		Other nitrogenous bodies..	0.23
Soluble gums........	2.00	(Xylan, Araban, Pectin, etc.)	2.00
Free acids..........	2.00	Melassinic, Glutinic, Saccharinic acids, etc.	
Combined acids......	3.00		5 00
Total..........100.00%			100.00%

.Molasses also contains a small quantity of carmelization product, the amount of these depending upon the temperature of evaporation and boiling.[1]   Caramel is always formed by overheating cane-sugar and is a mixture of several dark-colored bodies of uncertain composition.

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[1] Caramelan, Caramelen, Caramelin, see von Lippmann, Chemie der Zuckerarten, 3d ed., 1210.

OPTICAL METHODS IN SUGAR ANALYSIS.

APPARATUS AND MANIPULATIONS.

67. The Polariscope. — The instrument used in the quantitative estimation of sugars by the optical methods is usually called a polariscope. The names " polarimeter" and " saccharimeter" are also sometimes used

Sucrose, in common with many sugars and other substances, has the property of rotating the plane of polarization of a ray of light. Advantage is taken of this property in the construction of the polariscope.

The polarization of the ray of light is accomplished by passing it into a Nicol prism. This prism is made from a rhombohedron cut from a transparent crystal of Iceland spar. The end surfaces of the prism, Fig 18, are ground off so that the acute angles are each 68°. The prism is then
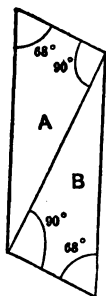
FIG. 18.

cut into two parts, A and B, through the obtuse angles and the surfaces are polished and cemented together again, in their original positions, with Canada balsam. Other forms of the prism are used, but this description will answer for the present purposes.

On passing a ray of light into this prism it is separated into an ordinary ray, which is reflected from the prism by the balsam cement, and an extraordinary or polarized ray, which passes through the polariscope and upon whose properties the construction of the instrument depends.

Confining our remarks to three sugars of most interest to the cane-sugar chemist, it should be noted that sucrose

rotates the plane of polarization to the right and is there-
fore termed a right-hand sugar. The expressions dextro-
rotatory and dextrogyratory are also applied to sucrose.
Dextrose also rotates the plane to the right. Levulose
rotates the plane to the left and is laevorotatory, or a left-
hand sugar. Quartz is of two kinds, right and left hand,
and is used in certain types of polariscopes to compensate
for the rotation due to sugar.

The power of a sugar to rotate the plane of polarization
differs for different sugars. The number expressing this, as
determined under certain standard conditions, is termed the
specific rotatory power.

If the polarized ray is passed through sugar solutions of
different concentrations, or through columns of the solution
of different lengths, it will be observed that the amount of
rotation varies with the strength of the solution and the
length of the column.

These properties of sugars, Iceland spar, and quartz are
utilized in the construction of the polariscope, and keeping
them in view the descriptions of the various types of
instruments, as given farther on, will be readily under-
stood.

Polariscopes may be divided into two classes, viz., shadow
and transition tint-instruments. The shadow-instruments
may be subdivided into polariscopes using white light, as
from a kerosene-lamp, and those requiring a monochromatic
light, the yellow ray. The former are usually employed
in commercial work and the latter in scientific investiga-
tions.

A brief description of the polariscopes in general use
will be given in the following paragraphs and will be
sufficient for the purposes of this book. The reader is
referred to hand-books of the polariscope for more de-
tailed descriptions of the theory and construction of the
instruments.

68. Half - shadow   Compensating   Polariscope.
(Schmidt & Haensch).—The optical parts of this instru-
ment are indicated in Fig. 19. The polariscope shown in
the figure is of the single compensation type.

At O there is a slightly modified Jellet-Corny Nicol prism,

at G is a plate of levorotatory quartz, at E is a quartz-wedge movable by means of the screw M, and at F is a quartz-wedge, fixed in position, to which is attached the vernier. The scale upon which to note the distance the

Fig. 19.
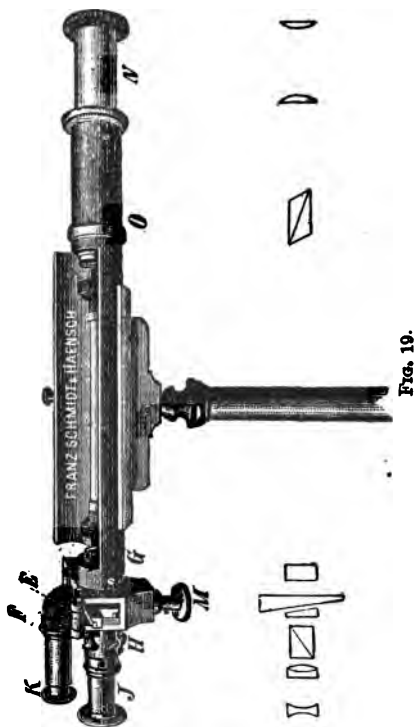
quartz-wedge E has been moved, in compensating for the rotation of the plane of polarization due to interposing an optically active body, is attached the wedge. The scale is graduated, for technical work, to read percentages of cane-sugar. These quartz-wedges are of dextrorotatory quartz.

The parts G, E, and F constitute the compensating apparatus, *i.e.*, that compensates for the deviation of the plane of polarization, as explained above. The substance to be examined, dissolved in a suitable solvent, is placed in the observation-tube, as shown in the figure. At H is the analyzer, a Nicol prism; at J is the telescope used in observing the field, and at K are the telescope and reflector for reading the scale. The two lenses at the extreme right are for transmitting the rays of light from the lamp in parallel lines to the Nicol prism, forming the polarizer.
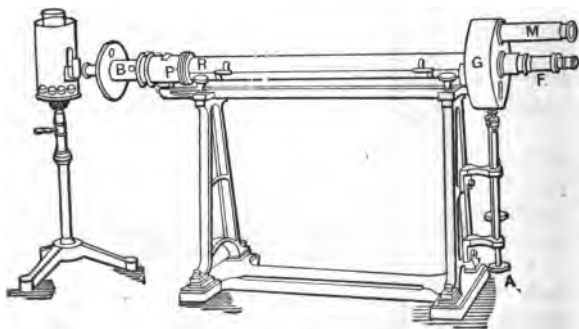
FIG. 20.

The instrument described above is of the single-compensation type. A double-compensating instrument is shown in Fig. 20. This polariscope differs from that already described in having two sets of quartz wedges of opposite optical properties and two scales and verniers. The arrangement of the wedges is shown in Fig. 23.

The field of vision of the above instruments, when set at the neutral point, is a uniformly shaded disk. If the milled screw, controlling the compensating wedge, be slightly turned to the right or left, one-half of the disk will be shaded and the other light. It is from this half-shaded disk and the compensating wedges that this instrument takes its name.

A double-compensating instrument of recent construction is shown in Fig. 20. The optical parts of this instrument are protected from exposure by the cap G, and by plain glass plates. This protection of the optical parts is especially important in the tropics, where, owing to some peculiar climatic condition, the lenses often become coated with an opalescent film that can only be removed by polishing. These plates also prevent minute spiders and other insects in the tropics from damaging the instrument. The scale is lighted from the lamp, the light being reflected by means of a prism and mirrors. The telescope F is focused by a screw. The screws for adjusting the position of the quartz wedges have long stems so that the hand of the observer may rest upon the table. A glass cell filled with a three per cent solution of bichromate of potassium is placed at B and serves as a ray-filter.[1] This ray-filter should always be used, varying the strength of the solution to suit the requirements of the work in hand. The prism at P is more readily accessible than in the older instruments, and all lenses and other optical parts are protected by glass covers. An important improvement is the substitution of a very substantial stand for the ordinary tripod support.

69. Half-shadow Polariscope with Glass Scales (Josef-Jan Frič).—The instrument shown in Fig. 21 has double-wedge compensation for use with white light. The optical parts are enclosed in a metal case for protection from dust. The scales and verniers are engraved on glass and are lighted by a part of the polarized rays which are reflected upon them.

Messrs. Frič also make a quartz-wedge polariscope with adjustable sensibility, designed for the U. S. Bureau of Standards by Frederick J. Bates. This instrument is double

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[1] This strength of solution assumes a cell 3 cm. in length. For other cell lengths, the product of the length by the percentage strength of the solution should be 9. According to Schönrock the use of a bichromate ray filter makes a difference of 0.12° in the polarization with a white light instrument. With the filter he obtained a reading of 100° and without it 100.12°. (Circular No. 44, Bureau of Standards; Z. Ver. Deut. Zuckerind., 1904, pp. 521–558.)

quartz-wedge compensating and has a Lippich polarizing-system. Readings may be accurately made to 0.01° sugar. The Frič instruments are graduated according to the specification of the International Commission at 20° C. and use

the normal weight of 26 grams with the 100 true cubic centimeter flask at 20° C.

70. Half-shadow Polariscope (Julius Peters).—This instrument, Fig. 22, is double-compensating. It is similar in principle to the other compensation polariscopes. The

optical parts are protected by glass plates from the action of the atmosphere. A dust-cap, not shown in the figure, protects the optical parts at the front end of the instrument.
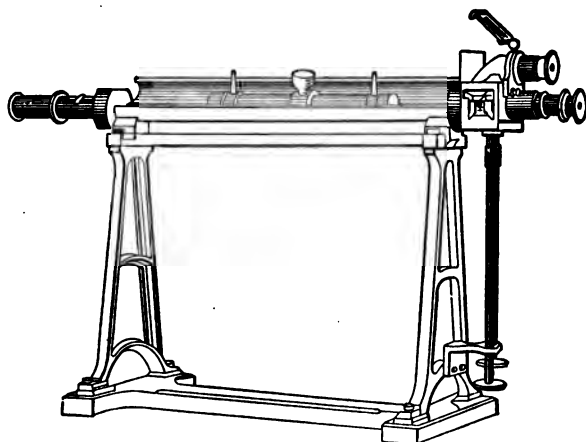
FIG. 22.

The quartz wedges are not mounted in brass as is usual, and it is claimed are not exposed to pressure or strain with the expansion of metal. As is well known, the rotation of quartz is changed by pressure.

71. Triple-field Polariscope (Schmidt & Haensch).— This instrument differs from those already described in having two small Nicol prisms placed in front of the polarizer, as shown in Fig. 23. The field of the instrument is divided into three parts, 1, 2, and 3 of the diagram, Fig. 24. This figure shows the arrangement of the Nicol prisms (I, II, III), and a diagram of the field. When the instrument is set at the neutral point, the field is uniformly shaded; in other positions 1 is shaded and 2 and 3 are light or *vice versa*.

This arrangement permits a very high degree of accuracy in the adjustment of the field, in polariscopic observations.

According to Wiley [1] this instrument is extremely sensitive and is capable of results but little inferior to those with the
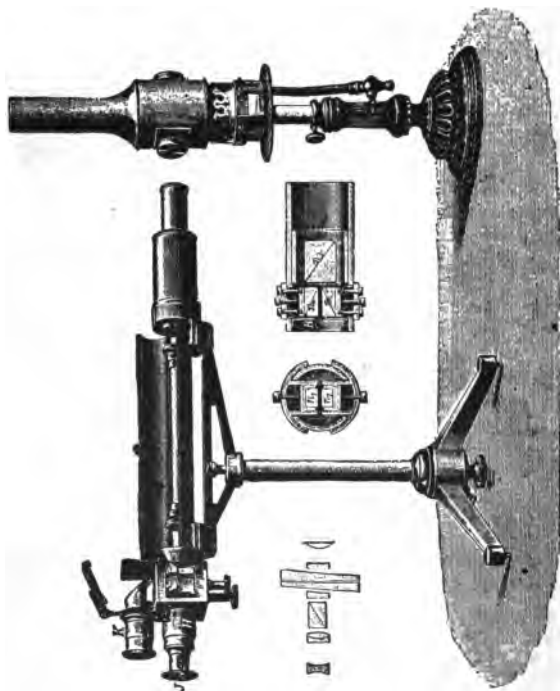
Fig. 23.

Landolt-Lippich polariscope, which is constructed for the very careful scientific researches.

72. Laurent Polariscope (Maison Laurent).—The Laurent (Fig. 25) was originally a half-shadow instrument for use only with a monochromatic light, but these polariscopes are now made with either half-shadow or triple field, and are also provided with a compensation attachment for use with white light.

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[1] Agricultural Analysis, 3, 91.

In the Laurent polariscope, using monochromatic light, the analyzer is revolved by means of a milled screw, to compensate for the rotation of the plane of polarization by the sugar solution. The angular rotation is measured by means of a scale and vernier. The instrument also has a second scale, called the cane-sugar scale, on which percentages of sugar may be read directly.

As stated, there is a compensating device for the Laurent polariscope, which may be attached to the front end of the instrument, as shown in Fig. 26, and permits the use of white light.

A distinctive feature of this polariscope is the adjustable polarizer. The Nicol prism may be rotated through a small angle, thus varying the amount of light that passes, and at the same time the sensitiveness of the instrument.

Fig. 24.

The polarized light is passed through a disk of glass, half of which is covered with a thin plate of quartz, thus producing the half-shadow feature of the instrument.

This type of polariscope is much used in scientific research, since it has no quartz wedges to be affected by variations of temperature.

73. Transition-tint Polariscope. Soleil-Ventzke-Scheibler.—This instrument, Fig. 27, resembles that described in **68** in general appearance, but actually differs radically from it. It differs from the half-shadow instrument in having an additional Nicol prism at A and a quartz plate B which produce the color. The tint of the field is varied by means of the spur-wheel and pinion, revolved by the rod L. The optical parts at the front end of the polariscope are the same as those in the Schmidt & Haensch half-shadow instrument.
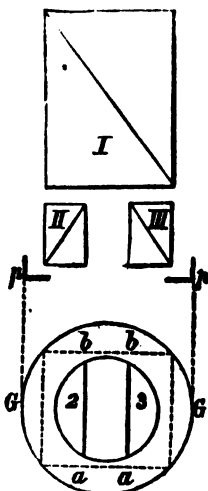
The field is colored, and when the instrument is set at the neutral point the tint is uniform.   The sensitive tint for
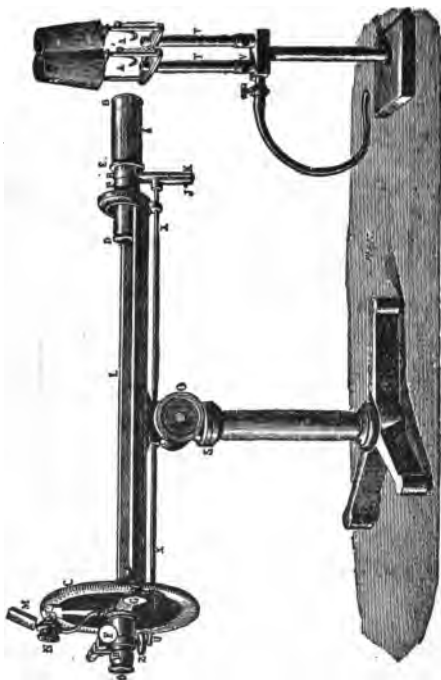
FIG. 25.

most eyes is a rose-violet. The tint may be varied by revolving the rod L.

74. General Remarks upon Polariscopes.—Polariscopes in general are similar in construction to the types described, differing only in details of construction.

Half-shadow and triple-field instruments are most generally used.   These polariscopes are very sensitive and reliable.

The Laurent type of saccharimeter is extensively used in France and Belgium, and except the higher-grade instruments in research work is but little used outside those countries.   The necessity of a dark room and a monochro-

matic light render the original Laurent polariscope unsatisfactory for use in the cane-sugar industry. The Laurent modified for use with white light is a convenient instrument.

The transition-tint instruments were formerly used almost exclusively, especially in the United States, but have been

FIG. 26.
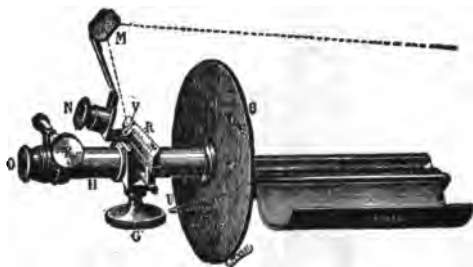
largely replaced by shadow polariscopes. Tint instruments, obviously, cannot be used with accuracy by persons more or less color-blind, and in the analysis of dark-colored materials it is frequently difficult to secure solutions that are clear enough for observations.

All polariscopes are fitted to receive observation-tubes 200 mm. long, and an instrument of this size is also supplied with a half-length or 100-mm. tube. Other polariscope lengths are 400 mm. and 600 mm.

A 400-mm. polariscope is a satisfactory length for a factory using the milling process, but with the diffusion process the 600-mm. size is preferable.

75. The Polariscopic Scale. Ventzke Scale. The Normal Weight.—Polariscope scales are divided to read either circular degrees or percentages of cane-sugar or both. Commercial instruments usually have only the Ventzke or cane-sugar scale.

The Ventzke or cane-sugar scale is so divided that, if a certain weight of the material be dissolved in water and the solution diluted to 100 cubic centimeters and observed under standard conditions in a 200-mm. tube, the reading will be in percentages of cane-sugar, or if pure sucrose be

used, the reading will be 100. The weight required under these conditions to give percentage readings is termed the "normal weight" or the "factor" of the instrument. In commercial work, especially in the polarization of sugars,

Fig. 27.
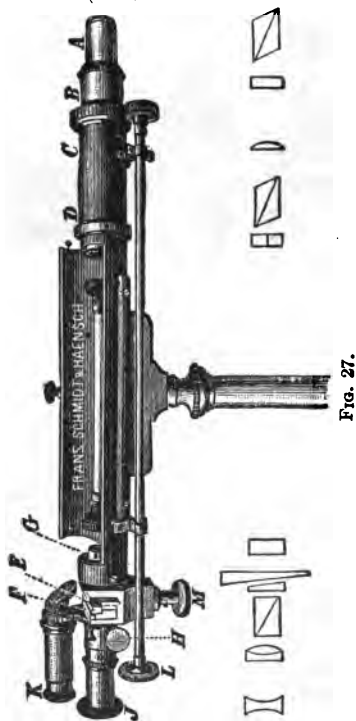
the divisions of the cane-sugar scale are usually termed "degrees."

The normal weight for the German instruments, which are very generally used throughout the world, as adopted by the International Congress of Applied Chemistry, is 26 grams. The flask used with this normal weight must hold

100 true cubic centimeters of solution at 20° C. The solution must be prepared and the observation be made at 20° C. to secure correct results.

The original normal weight and the one still most generally used is 26.048 grams and the material is to be dissolved in 100 Mohr's cubic centimeters or Mohr's units (see **80**) of solution, and is to be prepared and observed at $17\frac{1}{2}$° C.

The normal weight for the Laurent instrument is 16.29 grams of material, which should be dissolved and diluted to 100 true cubic centimeters at 20° C. and be observed at this temperature.

76. Manipulation of a Polariscope. — Methods of preparing the solutions will be described in **80**. Having dissolved and clarified the normal weight of the material to be polarized, fill an observation-tube with a portion of the solution and place it in the trough of the instrument, and pass the light from a suitable lamp through it.

The observer with his eye at the small telescope J of the instruments in Figs. 19, 20, 23, 27, or the corresponding part of the Laurent, Fric, and Peters polariscopes will notice that one-half of the disk is shaded or more deeply colored, according to the type of polariscope, than the other, provided the instrument is not set at the neutral point. The vertical line separating the half-disks should be sharply defined, and if not, the ocular should be moved backwards or forwards until a sharp focus is obtained.

The observer should now turn the milled screw, which moves the quartz-wedge compensator, or the analyzer of the Laurent, until the field appears uniformly shaded or tinted, then read the scale as directed in page 154.

In making the observation the eye should be in the optical axis of the instrument, and should not be moved from side to side.

A little practice will enable the operator to detect very slight differences in the depth of the shadow or tint and to attain great accuracy in this manipulation.

The manipulation of the triple-field polariscope is as described above, except that the field is in three sections, giving greater facility in shading it uniformly.

The double compensating polariscopes are provided with

two scales, in the older instruments, one graduated in black
and the other frequently in red. The black scale is operated
by the black screw and the red by the brass one. For ordi-
nary work the red scale is set at zero and the field is equalized
with the black screw.

Since the abandonment of ivory scales on account of their
length changing with certain atmospheric conditions, metal
scales are usually used, and are marked to indicate whether
for right or left readings.

To check the scale, remove the observation-tube and equal-
ize the field with the screw used for invert readings. Both
readings should agree.

To make an invert reading, *i.e.*, one with a lævorotatory or
left-hand sugar, the black, or right-hand, scale should be
set at zero and the other scale used. The readings should
be recorded with the algebraic sign minus. With the single-
compensating instruments the direct and invert readings
are made on the same scale, the graduations extending both
sides of the zero.

The Laurent instruments are fitted with a device for
rotating the polarizer through a small angle, thus varying
the sensitiveness. This is convenient in polarizing very
dark-colored solutions. A slight change in the position of
the adjusting lever will increase or decrease the amount
of light that passes through the instrument, though at the
same time increasing or decreasing the sensitiveness of
the polariscope.

Having equalized the field of the polariscope as already
described, the scale is to be read. The method of reading
the scale is best shown by an example. Let the position
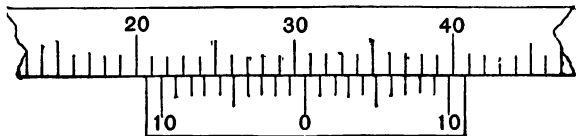
FIG. 28.

of the scale and vernier be as shown in Fig. 28. The zero
of the vernier is between 30 and 31 of the scale; record the
lower number and note the point at which a line on the

vernier corresponds with one on the scale, that is, if extended would coincide with the line on the scale, in this case at 7 of the vernier. Enter this number in the tenths place and the completed reading is 30.7. If the zero of the vernier falls directly opposite a line of the scale, the reading is a whole number. The divisions to the left of the zero of the vernier are only needed in single compensating instruments and are for making invert readings.

If the normal weight of sucrose, or of a substance containing sucrose and no other optically active substance, has been dissolved in water and diluted to a volume of 100 cc., and a 200-mm. observation-tube has been used, and the observation is made at the temperature at which the instrument was standardized, for the German instruments 20° C., formerly 17½° C., the reading on the sugar-scale is the percentage by weight of sucrose in the material. The readings must be corrected for other weights than the normal, for other volumes than 100 cc., and for other tube lengths than 200 mm.

77. Polariscope Lamps.—Compensating half-shadow instruments, the Laurent with white light attachment and the transition tint-polariscopes require a strong white light.

The most efficient polariscope illumination in a factory having twenty-four-hour electric service is the nitrogen-filled concentrated-filament Mazda lamp of 100 watts capacity. This light is so very intense that a ground-glass plate should be interposed in polarizing light-colored solutions.

Acetylene lamps provide a strong and convenient source of light, probably next to the concentrated-filament lamp in efficiency. The Welsbach lamp, burning gas, alcohol or gasolene, gives a very good light.

Messrs. Schmidt & Haensch equip many of their instruments with small electric-lamps operated from small secondary batteries. The lamp is provided with a special socket attached directly to the instrument. This arrangement of the lamp is not entirely satisfactory in the writer's experience. Kerosene lamps may be used and should have duplex burners. Electric and acetylene lamps and alcohol or gasolene Welsbach lamps are now so easily obtainable on plantations that they should be given preference in the order named over the kerosene light.

It is quite essential that the position of the light with respect to the polariscope be fixed. The intensity of the light should be as constant as possible, and if changed, the zero reading observation should be verified.

It is difficult under the usual factory conditions to provide a suitable monochromatic light for the Laurent type of instruments. The lamps used are the Laurent gas-sodium, the Landolt gas-sodium, and the Laurent eo'ipyle, the last named burning alcohol. These lamps require a flame such as that of a Bunsen burner, and the yellow color is imparted to it by contact with fused sodium chloride. M. F. Dupont [1] has experimented with various soduim salts for use in lamps for monochromatic light, and finds that sodium chloride and tribasic phosphate of sodium fused together in molecular proportions give results in every way superior to those with sodium chloride only.

78. Adjustment of the Polariscope. — The scale of the instrument is the only part liable to get out of adjustment. To test this adjustment, place a polariscope tube filled with water in the trough of the instrument and make an observation. This observation may be made without the tube, but the adjustment on the zero is not so readily made as with the water. If the scale is properly adjusted the reading should be zero.

The method of adjusting the Schmidt & Haensch instruments is the same for all of their compensating polariscopes and is similar to that used by other makers. A micrometer-screw, turned by means of a key, is arranged to move the vernier a short distance. The field is equalized as usual, but with water in the observation-tube, and the vernier is moved by the micrometer-screw until the zero lines of the scale and vernier coincide with one another. The scale is now moved through several degrees by the milled screw and the field is again equalized as before, and if the zero lines do not coincide the vernier is to be again adjusted. These manipulations are repeated until the zeros coincide in several successive observations. These adjustments are very

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[1] Bulletin de l'Association des Chimistes, **14**, 1041.

fatiguing to the eye, which should be rested a short time before making the final observations.

Certain compensating polariscopes, especially of the older models, are exceedingly sensitive to changes in the position or intensity of the source of light. It is advisable to follow the maker's directions as to the position of the lamp with regard to the instrument and arrange the latter so that it cannot be jarred out of place. The distance of the lamp from the instrument is usually 15 to 20 cm. The position the lamp should occupy should also be marked, that it may be properly replaced after refilling, and the intensity of the light should not be changed after adjusting the instrument until the observation has been made. A change in the position or intensity of the light, with certain instruments, will sometimes cause an error of 0.5° or more.

In adjusting the Laurent polariscopes to read zero, the lever U, Figs. 25, 26, is lifted to the upper limit, the ocular O is next focused on the vertical line which divides the field into halves; the zeros are now made to coincide by means of the screw G. The field should now be uniformly shaded, if the instrument is in adjustment, and if not uniform, equalize it with the screw F. The adjustment should be tested as with the other instruments, and repeated until satisfactory.

It is advisable to have quartz control-plates for checking the adjustment of the instrument and the correctness of the scale. Standardized plates of the highest accuracy may be obtained from the makers of polariscopes, and in use take the place of the observation-tube and a standard solution of pure sucrose. One plate should read approximately 96° and a second about 60°, as these parts of the scale are used in the most important polarizations.

The scale may be tested with a control-tube made by Schmidt & Haensch and shown in Fig. 29. The funnel T of the control-tube is filled with a sugar solution, which flows into the tube as it is lengthened by turning the milled screw. The tube length is read on the scale N. The illustration sufficiently describes this apparatus.

The committee of the Fourth International Congress of Applied Chemistry also recommends the use of pure cane-

sugar for testing the polariscope. The method of preparing this sugar and precautions in using it are described in **293.**

The micrometer-screw at *H*, Figs. 19, 20, 23, 27, is for the adjustment of the analyzer, should the field of the polariscope be unevenly shaded when set at the neutral point.

The analyzer and polarizer should not be removed from the instrument or adjusted except by an experienced workman, and in the event of an accident to the polariscope it should be returned to the dealer for repairs.

All parts of the polariscope should be kept very clean, especially the exposed parts of the lenses; these should be occasionally cleansed with alcohol and wiped with old linen.
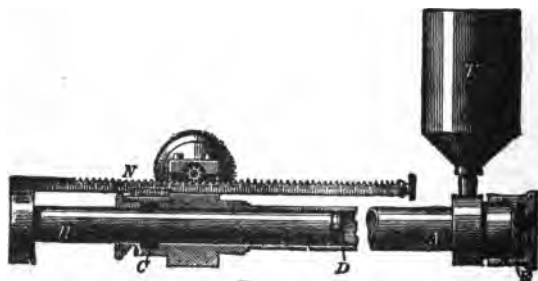
FIG. 29.

79. Observation Tubes.—The usual tubes of glass are shown in Fig. 30. The upper tube has screw-caps and the lower the Landolt slip-cap. The slip-cap is designed
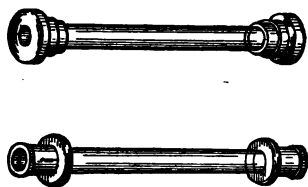
FIG. 30.

to prevent undue pressure upon the cover-glass. The tubes of the French Laurent instrument are supplied with slip-caps that have bayonet-catches. A coiled spring is arranged inside the cap to bear upon the cover-glass and hold it in position, without unnecessary pressure.

Metal observation-tubes are used in many laboratories. Account must be made of the expansion of the metal in very careful work, especially if the laboratory temperature fluctu-

ates greatly. Metal tubes are liable to distortion through careless handling and to corrosion with acids. These tubes are sometimes of silver or are plated with gold to prevent corrosion.

Tubes of the type shown in the illustration, Fig. 30, must be completely filled with the solution to be polarized. The cover-glass should be slipped sidewise onto the tube, pushing off the surplus liquid. The glass body of the filled tube should not be touched with the hands, since the warmth will cause striations to form in the liquid. These prevent an immediate observation. In the event of striations, the tube should be left in the trough of the polariscope until the field clears.

Observation Tube with Enlarged End.—This tube is shown in Fig. 31. In using this tube, it is nearly filled with the

FIG. 31.

solution to be polarized, leaving room for a small bubble of air, which rises to upper part of the enlargement. This arrangement obviates the necessity of excluding air-bubbles, and facilitates filling the tube.

Bates' Observation Tube.[1]—"In order to overcome the prevalent defects in the theoretical design, as well as secure a tube suitable for severe usage, this Bureau (U. S. Bureau
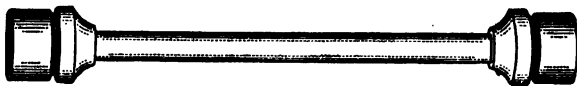
FIG. 32.

of Standards) has brought out the new Bates type of tube shown in Fig. 32. It will be observed that the weight is carried upon two shoulders, which are integral parts of the

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[1] Copied from Circular No. 44, " Polarimetry," U. S. Bureau of Standards, p. 39.

tube and not upon the caps, thereby eliminating all danger
from turning while in the trough of the instrument.   The
bore is 9 mm., permitting the utilization of the full aperture
of the polarizing system.   This also reduces to a minimum the
light depolarized by reflection from the walls of the tube.
The field of the instrument thus appears for the first time as
a bright, sharply defined circle with no overlying haziness,
and the reading can be made with increased accuracy.   Both
ends are enlarged with all the attendant advantages, yet
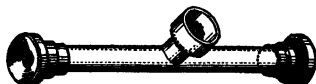
FIG. 33.

but one size of cover-glass and washer is required.   The
walls are unusually heavy, eliminating all danger from
bending."

  Observation Tube with Side Tubule.—The tube shown in
Fig. 33 is very convenient in general sugar-analysis.   The
cover-glasses need rarely be removed.   This arrangement
reduces the risk of error by compression of the cover-glasses.

FIG. 34.

The tubes should be frequently cleaned with diluted acetic
acid.
  Pellet's Continuous Tube.—This tube, Fig. 34, is designed
for very rapid polarization and is especially adapted to the
use of laboratories for beet-seed selection and the purchase
of raw material on a basis of its sucrose content.   The Pellet
tube is also convenient in the control of the char-filters in
sugar-refineries.
  The Pellet tube provides for the rapid change of solutions
without removing it from the trough of the polariscope.

The tube is so arranged that it may form a part of a syphon by connecting rubber tubing to the tubules. The short leg of the syphon terminates in a glass tube which is dipped into the new solution and a pinch-cock on the long leg is then opened. The incoming liquid displaces the previous solution. This arrangement should be used only with solutions of approximately the same polarization and not when scientific accuracy is desired. The funnel arrangement illustrated in Fig. 35 should be used when accuracy is necessary, and in its use liberal quantities of the solution should be used to wash the funnel.

The Pellet tube should be washed with distilled water before a period of idleness and should be left filled with water.

The first descriptions of this tube that came into the hands of the author were very meager, and several experiments were made before a satisfactory tube was constructed. These experiments were not made with a view to improving the construction of the tube as designed by Pellet, but to secure a tube for immediate use. The tube finally adopted by the writer is shown in Fig. 35 and differs from Pellet's design only in having four grooves to distribute the solution instead of one. The funnel directs the solution into an annular canal, which connects by separate openings with each of the four grooves shown at the end of the tube. The solution is delivered against the inner surface of the cover-

FIG. 35.

glass, and by a similar set of grooves and canal at the opposite end of the tube the displaced solution flows through a bent tube to the waste-jar. The observation cannot be made until the previous solution is entirely displaced. So long as any of the old solution remains the field will not be clear.

The Pellet tube with the funnel-inlet may be used with accuracy in the analysis of sugars. The funnel should be small and preferably of the form shown in Fig. 35. An improvement to the funnel would be an overflow attachment to facilitate the washing with the new solution.

The author has proposed substituting a grooved tube, such as a rifle-barrel, for the plain tube. The swirling motion imparted to the solution by the rifling would probably promote the removal of the previous solution, especially in testing sugars. Experiments made with a Pellet tube, pro-
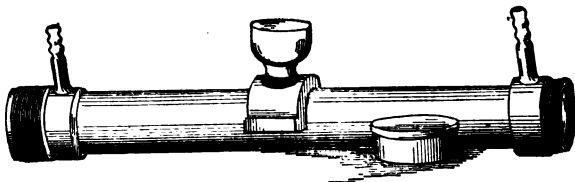
Fig. 36.
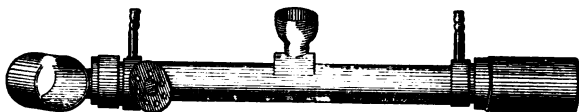
Fig. 37.

vided with a glass body, indicated the desirability of the grooves.

Landolt's Inversion Tube; Wiley's Modification.—This tube, Fig. 36, is arranged for the control of the temperature of the solution under observation, especially in the Clerget double-polarization method. The glass observation tube is enclosed in a metal jacket through which water is circulated while polarizing. A side tubule, enlarged to funnel shape, is provided for use in filling the tube and in taking the temperature of the solution. A centigrade thermometer graduated to fifths of a degree should be used.

Wiley devised the desiccator-caps shown in Fig. 37 to

prevent the condensation of moisture upon the cover-glasses at temperatures below the dew-point of the air. These caps are of hard rubber and have a central tube surrounded by fused calcium chloride to dry the air within the cap.

80. Special Sugar Apparatus and Preparation of Solutions for Polarization.—To facilitate descriptions,. apparatus and the preparation of solutions will be considered in rather illogical order.

Preparation of Solutions.—A solution of a definite concentration, sufficiently free of color and clear to transmit light, must be prepared. While solutions of various concentrations may be used, it is advisable to simplify the calculations by using a multiple or convenient fraction of the normal weight dissolved in 100 cc. of solution or a multiple of this volume number.

Dissolve the normal weight [1] of the material contained in a 100-cc. flask, in water and add sufficient subacetate of lead solution, or of the normal acetate, according to the material to be tested, to precipitate all of the matter precipitable by the reagent. Complete the volume of the solution to the 100-cc. mark of the flask. Mix the contents of the flask thoroughly and pour upon paper for filtration. The entire contents of the flask should be poured upon the paper at once. Reject the first portions of the filtrate or all of it until a perfectly clear solution is obtained. These portions should be used in rinsing the receiving-vessel. The first portions of the filtrate contain the moisture displaced from the filter-paper. If the filtration is slow or the analysis is to be especially accurate, and always in the analysis of sugar, the funnel should be covered during filtration to prevent evaporation. Portions of the filtrate should not be poured back through the filter in careful work.

The above description covers the preparation of solutions in a general way. Detailed descriptions will be given in connection with the analysis of the various materials, especially as regards the use of the clarifying agents. The quantity of subacetate of lead to be used in clarifying solutions can

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[1] With the normal weight, 26.048 grams, use the Mohr cc. flask and with International Committee's weight, 26 grams, use a true cc. flask.

be given only approximately on account of the variations
in the materials themselves and in the illumination of the
polariscope. In general the minimum quantity of the lead-
salt that will yield a clear and sufficiently light-colored solu-
tion should be used. Excessive use of lead introduces im-
portant errors into the analysis. The following numbers
refer to cubic centimeters of the lead solution of 54.3° Brix
per one normal weight of the material: Raw juice, 1.5 to
.2.5 cc.; sirup, 7 to 10 cc.; molasses of 20° Brix (vacuum-pan
control), 5 to 10 cc.; first molasses, 7 to 10 cc.; final molasses,
25 to 30 cc.; 96° raw sugar, 2 to 4 cc.; 98° raw sugar, 1 to 2
cc.; 80 to 89° second sugar, 5 to 7 cc.; filter press-cake,
6 cc.

Horne's dry subacetate of lead may very often replace the
solution of the salt with advantage. (*See* page 179.)   Ap-
proximately 1.25 to 1.5 grams of the salt is required per
100 cc. of raw juice and a like proportion for other materials.
. Paragraphs 83, 84, relative to the influence of the lead-salt
upon the sugars and the volume of the precipitates should be
consulted.

Alumina-cream should be used in addition to the subace-
tate of lead in clarifying the solution in testing a sugar.
The alumina-cream alone is usually sufficient in the analysis
of high-grade sugars.

It is usually advisable to add a little of the lead reagent
to the sugar solution, mix thoroughly, await the subsidence
of the precipitate and then test the supernatant liquid with
a drop of the reagent to ascertain whether more lead is re-
quired. An experienced operator can readily judge by the
appearance of the precipitate whether the lead has been used
in sufficient quantity. The reagent should be measured in
routine work and in so far as is possible the same quantity
should always be used with similar materials.

The materials in sugar analysis are most conveniently
weighed in a nickel or German-silver capsule, made especially
for this purpose. (Fig. 38.) The solutions do not adhere
to the polished surfaces of the capsule and the shape of this
is such that the material may be very readily washed into
the flask. The capsules lose weight gradually through use.
The counterpoise should not be filed to correct for this loss,

but the stem or plug should be unscrewed and sufficient lead be removed from the cavity to compensate.

If the sugar-flask has a narrow neck, as is prescribed in careful work, it requires skill to wash sugar or other material into it. This operation is facilitated by inserting the stem of a small German-silver funnel, made for the purpose, into the neck of the flask. This should reach to just below the neck, thus keeping the sugar from contact with the latter. The solution adhering to the capsule and funnel should be washed into the flask with a jet of water. Sufficient room must be left in the flask—about 20 cc.—to permit giving the liquid a rotary motion, for dissolving the material.

The flask should be held by its neck to prevent the hand from warming the solution. From time to time it should be examined from below to note whether undissolved material

FIG. 38.

remains. After solution of the material and its clarification with lead subacetate as has been described, the volume should be completed to the mark with water. Should drops of water adhere to the neck of the flask they should be absorbed with strips of filter-paper. The water used in preparing the solutions should be either distilled or other water free of optically active substances.

The contents of the flask should be thoroughly mixed by shaking and be poured immediately upon the filter. The filter should be of paper suitable for rapid filtrations, and should be fluted or "star" folded or a ribbed funnel should be used. The funnel and paper should be large enough, especially in analyzing sugars, to receive the entire contents of the flask. The filter should never be so large as to project above the edges of the funnel. The first few cubic centimeters of the filtrate should be used in rinsing the filtering-cylinder and should then be rejected. If the

filtrate should not be bright and clear it may be returned to the filter, but this is not usually to be recommended.   It is always preferable in analyzing sugars and other materials requiring considerable accuracy to reject portions of the filtrate until it runs clear.   If the filtrate does not clear, it is best to prepare a new solution, changing the quantity of subacetate of lead.   The polarization should never be attempted except with perfectly clear solutions.

It may sometimes be difficult to obtain clear solutions with the juice and products of unsound cane.   The addition of a little common salt or sodium phosphate followed by refiltration will often remedy this, or both the salt and kieselguhr
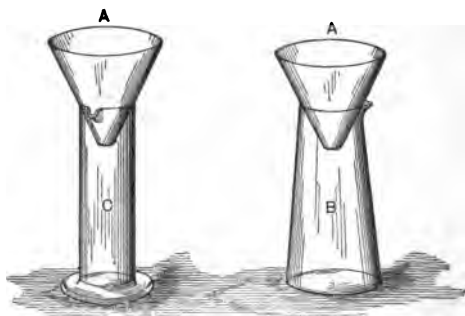
Fig. 39.

may be used.   Occasionally the difficulty may be due to insufficient subacetate.   If so, a little of Horne's dry subacetate should be added.

Filtering Devices.—A convenient filtering arrangement is illustrated in Fig. 39.   *A* is a stemless funnel, *B* a quarter-pint precipitating-jar, and *C* a small cylinder.   A plain cylinder is preferred by many chemists to the lip-cylinder, as the funnel makes a closer joint with the edge.

Stemless funnels, 4 inches in diameter, made of good tin-plate or of thin copper, planished, are more convenient, except for invert solutions, than glass.

The advantage of the metal stemless funnels and heavy glass precipitating-jars or cylinders is the ease with which

they may be washed and dried. The jar and cylinder are very convenient supports for the funnels.

Sugar-flasks.—The flasks used in sugar-work are usually graduated to hold 50 cc. 100 cc., or multiples of 100 cc. They are also graduated with two marks, viz., 50–55 cc., 100–110 cc., etc., and are then called "sugar-flasks" by the dealers.

Orders to dealers for flasks and other precision ware should be very specific in stating the system of graduation, whether to Mohr's cc. or units, or metric cc. It is important that all such ware in the laboratory be of the same system of graduation. Mohr's units should be used with the old normal weight of 26.048 grams and the metric or true cc. at 20° C.
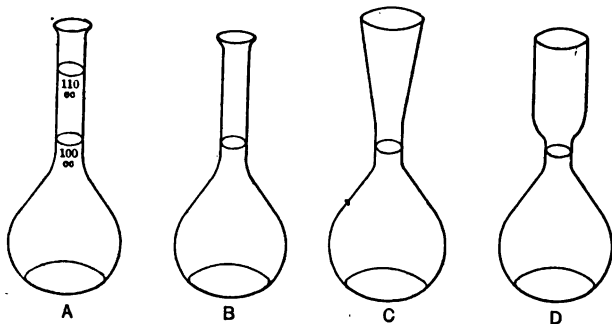
FIG. 40.

with the normal weight of 26 grams, that adopted by the International Commission for Uniform Methods.

Flasks should be made from glass tubing of uniform bore and circular cross-section. The shape of the body of the flask should approximate that of the diagrams in Fig. 40. A flask of this form gives little trouble from air-bubbles.

Flasks for commercial work often have necks of larger internal diameter than those used in the U. S. Customs laboratories or in research work. This is unnecessary and the diameters specified below should be adhered to. The following maximum internal diameters of the neck and limits of tolerance of error in the capacity of flasks are specified by the U. S. Bureau of Standards:

Capacity of the flask, cc.	Internal diameter of the neck, mm.	Tolerance of error, cc.
50	10	0.05
100	12	0.08
200	13	0.10
250	15	0.12
500	18	0.15
1000	20	0.30

This limit of tolerance is apparently large for flasks of such small neck diameter. Of several hundred flasks purchased of a prominent dealer for the laboratories under the direction of the writer and bearing the maker's certificate of calibration, all were well within the tolerance limits given in the table.

The 100 cc. flasks specified for use in the U. S. Custom House laboratories are like *B* of Fig. 40. These have a height of 130 mm. The neck is 70 mm. in length and its internal diameter must be not less than 11.5 mm. and not more than 12.5 mm. The graduation marks shall be not less than 30 mm. from the upper end and 15 mm. from the lower end of the neck.

The flasks shown in Fig. 40 all conform in shape of the body with the U. S. Customs regulations. They should be distinctly marked with their capacity and the system of graduation, *e.g.*, "Contains 100 cc., 17.5/17.5° C." for the Mohr flask and "Contains 100 cc., 20° C." for the metric or true cubic-centimeter flasks. The graduation-mark should completely encircle the neck of the flask.
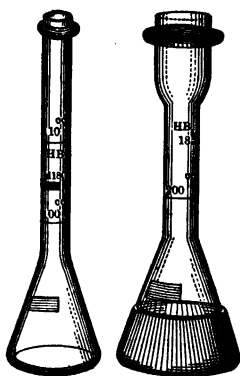
FIG. 41.

Pellet's conical flasks, Fig. 41, are of strong glass and have a rubber cover to slip over the bottom and a ring for the neck to reduce breakage. Their form gives them great stability and facilitates the escape of air-bubbles.

Referring to Fig. 40, the flasks A and B of various capacities fill most of the requirements of the sugar-house laboratory. The Stift (C) and Kohlrausch (D) flasks are used in the analysis of filter press-cake. The flask C if narrow at the graduation may be used in all classes of work.

The flasks should be frequently and thoroughly cleaned. C. A. Browne [1] recommends cleaning with a warm solution of sodium hydroxide and Rochelle salts, such as is used in preparing Fehling's solution. This removes the film of lead carbonate that deposits upon the walls of the flask. Strong commercial muriatic acid is usually used for this cleaning in sugar-house laboratories. Treatment with nitric acid, followed by washing and then a strong solution of chromic acid in concentrated sulphuric acid, is good preparation of flasks for calibration. It is advisable to use the chromic acid solution frequently in cleansing flasks. After this treatment the drops of water will drain from the neck of the flask properly instead of adhering to it.

Calibration of Sugar-flasks.—No flask should be used in important work without having first verified its marked capacity. There is much confusion on the part of manufacturers between the true and Mohr's cc., flasks of the one system being sometimes marked as having been graduated to the other.

Cleanse the flask as has been described above and thoroughly dry it in an oven. On cooling the flask note whether moisture has condensed upon the inside walls and if so return the flask to the oven.

The weighing should be by substitution to eliminate errors of the balance itself. Cool the flask to room temperature in the balance case, but do not wipe it again, and then accurately counterpoise it, placing it upon the left-hand balance-pan. Pieces of metal or weights may be used in counterpoising. Remove the flask from the balance and counterpoise the weight on the right-hand pan with accurate weights substituted for the flask. This gives the weight of the flask to the limits of accuracy of the analytical weights. Fill the flask to the mark with recently boiled distilled water

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[1] " Handbook of Sugar Analysis," p. 171.

of room temperature. A large pipette should be used in running the water into the flask to avoid so far as is possible wetting the neck. Remove water that may adhere to the neck of the flask, with a roll of filter-paper. Verify the filling of the flask by holding it by the upper part of the neck with the graduation at the level of the eye. If the lower part of the curve of the meniscus is not in line with the graduation-mark, add or remove water by means of a small pipette and bring it into line.

Place the filled flask upon the balance-pan as before and counterpoise it with pieces of metal or weights. Remove the flask and note the temperature of the water with an
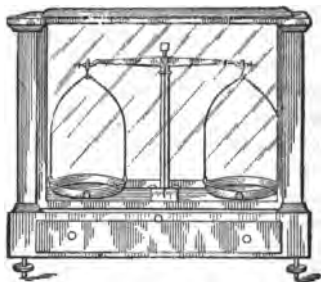
Fig. 42.

accurate thermometer. Counterpoise the metal with the analytical weights and record this weight as that of the flask and water. Deducting the weight of the flask gives the correct weight of the water whether the balance is in proper adjustment or not.

Reference is now had to the tables, pages 452 and 453, showing the weight of 100 cc. (according to Mohr or to the true cc. table) at various temperatures. For example: Our flask contains 99.958 grams of water at 20° C. Reference to the table shows this to be the apparent weight of 100 Mohr's cc. at 20° C., hence the flask is correctly graduated to this system. Similarly using the same flask and weight of water and the table of corrections for true cc. at 20° C. The correction at 20° C. is +0.282, which added to 99.958

gives 100.240 cc. as the true capacity of the flask. For comparison only, subtracting .006, the cubical expansion of the Mohr's flask from 17.5° to 20°, we have $100.240 - .006 = 100.234$ cc. These numbers show the actual relation between flasks graduated to true and Mohr cc., viz., 100 : 100.234.

81. Balances. Wash-bottles. Stock-bottles. Heating Devices.—*Balances.*—Convenient types of balances
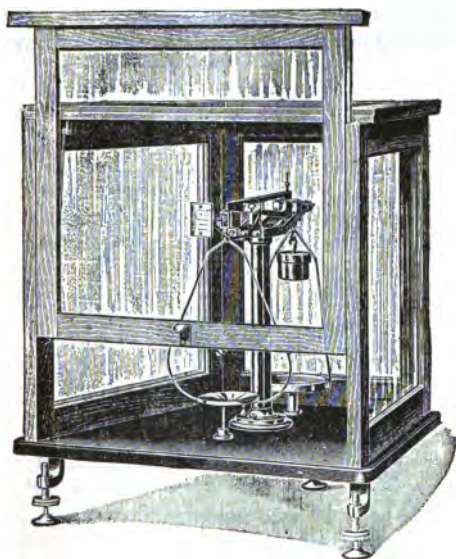
Fig. 43.

for sugar work are shown in Figs. 42, 43 and 44. In addition a good analytical balance and a set of high-grade weights are required. The analytical balance is used in ash determinations, glucose tests, calibration of sugar flasks and in the many special investigations. A "sugar" balance of good accuracy and a capacity of about 300 grams is needed in weighing samples for polarizations. For use in tropical and subtropical countries this balance should be fitted with agate bearing and knife edges. The balance

shown in Fig. 42 is suitable.   The decimal balance, shown in
Fig. 43, is a very convenient type for very rapid weighings
of the same quantity, *e.g.* the normal weight of a sugar.
In the balance illustrated, 10 grams in the pan at the back
of the instrument counterpoise 1 gram in the other pan.
Two sets of sugar weights, normal and half normal, should
be provided.   One set of these weights should be kept in
reserve for verifying and checking the weight of the others.
The balances should at least be sensitive to two milligrams
with a full load in the pans, though weights of sugar materials
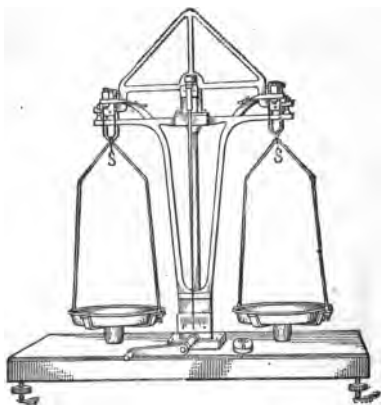
FIG. 44.

for polarization, to within 2 milligrams are usually sufficiently
accurate.   The errors that may be introduced through evapor-
ation or absorption of moisture in slow weighing are of more
importance than weights to within 2 milligrams.
   The bullion type of balance shown in Fig. 44 is very con-
venient for the so-called rough weighings in which large
capacity and speed of manipulation are essentials.   This
balance should be placed in a glass-framed hood to protect
it from dust and currents of air.   This instrument is made in
several capacities.   That of 5 kilograms, sensitive to 100
milligrams, is a suitable size.   It should have agate bearings

and knife edges for tropical work. This scale is suitable for use in bagasse analysis and in determining the degree Brix of massecuites and molasses.

Wash-bottles. Stock-bottles. — The water and the lead solution for use in sugar analysis, should be kept in large bottles on a shelf above the work-table. The water-bottle should have a glass syphon-tube with rubber connections, a pinch-cock and glass-nozzle, forming a convenient arrangement for washing samples into the sugar-flask and for diluting the solutions to the graduations on the necks of the flasks. This is a very satisfactory form of wash-bottle, and several of these should be distributed about the laboratory. The lead subacetate bottle should be connected with a reservoir-
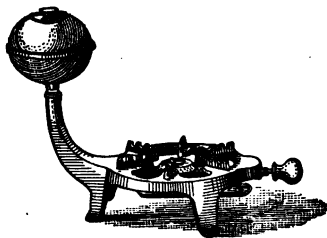
FIG. 45.

burette. The burette has a three-way cock, one opening connecting with the stock-bottle by means of a glass syphon and a rubber tube. The air-inlet to the subacetate-of-lead bottle should be provided with a small wash-bottle containing caustic soda solution, to absorb the carbonic acid and prevent precipitation of the lead. This is not strictly necessary, since a small precipitation is not objectionable, but where very large stock-bottles are used the washing arrangement should be employed.

Where lead subacetate solution is used in storing samples of juice a stock-bottle containing the concentrated solution should also be provided.

Heating Devices.—The electric hot-plate is the most convenient heating device for laboratories having a 24-hours

electric service. Where the generators are only operated at night the hot-plates must be supplemented by stoves. The Norma alcohol stove Fig. 45 is satisfactory for heating in inversions, extractions, etc.

82. Notes on Polariscopic Manipulations.—The screw-caps of the observation-tubes should not bear heavily upon the cover-glasses, since glass is double-refracting under these conditions and does not quickly recover its normal condition. A large error may be introduced through excessive pressure on the glasses. The cover-glasses should be of the best quality of glass, perfectly clean and with parallel sides. A glass may be tested with regard to the parallelism of its surfaces by holding it in front of a window and looking through it at a window-bar; on revolving the glass slowly between the thumb and a finger, if the bar appears to move the surfaces are not parallel and the glass should be rejected. Old glasses which have become slightly scratched should not be used. Glasses and observation-tubes should be frequently washed with acetic acid.

The planes of the ends of the observation-tubes should be perpendicular to the axis of the tube. This may be tested by placing a tube filled with a sugar solution in the trough of the polariscope and making an observation; on revolving the tube in the trough, and making observations at different positions, should the readings vary, the ends of the tube have not been properly ground.

The manufacturers of polariscopes and their accessories have attained such accuracy in their methods that faulty apparatus rarely leaves their workshops, nevertheless the scales and accessories should be checked to verify graduations, and tube length.

The polariscope should be used in a well-ventilated room. It should be protected from the heat of the lamp and, so far as practicable, from light from other sources. A convenient arrangement is to place the instrument in a box, leaving one end open. The lamp is placed outside the box, opposite the open end, and lights the instrument through a small opening. In making a reading, the observer stands at the open end of the box, his body cutting off the greater part of the extraneous light. The inside of the box should

be painted black. The polariscope should be fastened to
the bottom of the box or table, so that it may not readily
be jarred out of position.

The illumination of the scale is effected by reflecting
light from the polariscope lamp upon it, except in the old
models of instruments. A small electric lamp should be used
in the absence of reflectors. The current may be conven-
iently supplied by dry-batteries and should be controlled
by a bell push-button. A gas-jet or candle should never be
used for this lighting on account of overheating the scale or
damaging the polariscope.

The zero setting of the polariscope scale should be fre-
quently verified, using standardized quartz plates. The
bichromate filter-cell (see page 145) must always be used in
this verification and in adjusting the vernier. In fact this
ray-filter should never be removed from the polariscope
except for refilling or on account of the dark color of the solu-
tion to be tested.

**83. Influence of the Volume of the Lead Precipi-
tate.**—The lead precipitate introduces errors into the polari-
scopic analysis, some of which are probably offset by compen-
sating errors, notably in the analysis of low-grade products.
The error due to the volume occupied by the precipitate will
be considered in this paragraph, and those due to influence of
the lead upon the sugars and other optically active bodies
will be discussed farther on.

It is evident that if a part of the volume of the flask be
occupied by a solid, and there be no compensation for the
volume so occupied, the polariscopic reading will be too
high. This matter has been studied by numerous chemists,
but more especially in connection with the beet-sugar and
refining industries.

It was noticed by Rafe and Pellet, Commerson, and others
that in low-grade products, the saline coefficient of which is
high, there is apparently no error due to the volume of the
large precipitate. They attributed this fact to an absorption
of sucrose by the precipitate at the moment of its formation.
From numerous experiments Sachs[1] concluded that there
is no absorption of sucrose, and attributed the results with

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[1] Revue Universelle de la Fabrication du Sucre, 1, 451.

low products to the influence of the acetates of potassium and sodium formed with the acetic acid from the decomposition of the lead salt, upon the rotatory power of the sucrose. This view is strengthened by the fact that there is a very perceptible error, in the polarization of both beet and sugar-cane juices, due to the precipitate. In the precipitation of the impurities of juices but little of these acetates is formed, whereas with low products the quantity is large.

Sachs's[1] experiments were made by increasing the concentration of the solution instead of by dilution as practiced by Scheibler. The following data are from Sachs's paper: He dissolved x grams of molasses in water, added sufficient of the lead salt for clarification, completed the volume of the solution to 100 cc., and polarized as usual. The quantity x increases from experiment to experiment by equal increments. Since the quantity of molasses is increased with each experiment the volume of the precipitate must increase in the same ratio. An increase in the volume of the precipitate, if this were the only disturbing influence, should increase the polarization more than is due to the sugar, since the volume of the solution is decreased.

Letting $x =$ the weight of molasses, and $y =$ the polariscopic reading, the ratio $\frac{y}{x}$ should increase with the concentration, if there is an error, due to the volume of the precipitate, not compensated by other influences. Sachs used quantities of beet-molasses ranging from 5 to 35 grams in 100 cc., and substituting the values of x and y in the ratio and reducing he obtained the following figures:

1st Series......1.906   1.900   1.900   1.906   1.896
2d   " 2.14   2.13   2.14   2.14

The practically constant value of the ratio shows that minus errors have fully compensated for that due to the volume of the precipitate.

In a similar experiment with beet-juices Sachs obtained the following numbers:

1st Series.......0.5446   0.5474   0.5480   0.5497
2d   " 0.5800   0.5830   0.5842   0.5860

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[1] Revue Universelle de la Fabrication du Sucre, 1, 451.

The increase in the ratio with juices shows that there is an error due to the volume of the precipitate and there is not sufficient compensating error to correct it.

Experiments by the author in Cuba with cane-molasses gave results similar to those of Sachs, and several series of unpublished analyses of cane-juices made by L. R. Cook, at the writer's instance, gave the following results:

Juice and lead	25 gr.:1 cc.	50 gr.:2 cc.	75 gr.:3 cc.	100 gr.:4 cc.
1st Series	0.628	0.628	0.632	0.633
2d "	0.628	0.630	0.633	0.634

Series No. 2 is a duplicate of No. 1. The polarization of the juice using the normal weight in 100 cc. was 16.36, and that using four times the normal weight in 100 cc. and dividing the polariscope reading by 4 was 16.49, showing an uncompensated error of 0.13 per cent of sucrose. The uncompensated error in the 2d Series, using the same juice, was 0.15.

In two other series of experiments by Cook, in the first of which the polarization was immediate and in the second after forty hours, the results were as follows:

Juice and lead	20 gr.:1 cc.	40 gr.:2 cc.	60 gr.:3 cc.	80 gr.:4 cc.	100 gr.:5 cc.
1st Series	0.690	0.691	0.690(?)	0.694	0.696
2d "	0.687	0.690	0.692	0.693	0.694

As in the case of Sachs's experiments with beets, this work of Cook shows that there is a very perceptible error in the analysis of cane-juices due to the volume of the precipitate.

Sachs [1] used the following method of determining the volume of the precipitate: Clarify 100 cc. of juice with sub-acetate of lead as usual, using a tall cylinder instead of a flask. Wash the precipitate by decantation, first with cold water and finally with hot water, until all of the sucrose is removed. Transfer the precipitate to a 100-cc. flask and add one-half the normal weight of cane-sugar, dissolve the sugar, and dilute the solution to 100 cc., mix, filter, and polarize, using a 400-mm. observation-tube. The results are calculated as follows:

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[1] Revue Universelle de la Fabrication du Sucre, 1, 451.

Let P =per cent of sucrose in the sugar;
   P' =the polarization of the solution, made up in the
        presence of the precipitate;
   x =the volume of the lead precipitate.

Then $x = \dfrac{100P' - 100P}{P'}$.

Example: Let $P = 99.9$;

           $P' = 100.77$.

Then $x = \dfrac{(100 \times 100.77) - (100 \times 99.9)}{100.77} = 0.86$ cc.

The following is the method of Scheibler [1] for correcting for the error due to the volume of the precipitate, and usually termed "Scheibler's double-dilution method": To 100 cc. of the juice add the requisite quantity of subacetate of lead for the clarification, complete the volume to 110 cc. of and polarize as usual; to a second portion of 100 cc. of juice add lead as before, complete the volume to 220 cc., and polarize.

Calculation: Multiply the second polariscope reading by 2, subtract the product from the first reading, multiply the remainder by 2.2 and deduct this product from the first reading. The remainder is the required reading for the calculation of the per cent sucrose:

Example.

     Degree Brix of the juices................18.0
     First polariscope reading (110 cc.).... 57.6
     Second   "   "   (220 cc.).... 28.7
$2 \times 28.7 = 57.4$; $57.6 - 57.4 = 0.2$; $2.2 \times 0.2 = 0.44$; $57.6 - 0.44$
$= 57.16 =$ corrected polariscope reading.   By Schmitz table, page 300 we have:

                    15.18
                     .03
                     .02
                    ─────
                    15.23 = required per cent.

[1] Zeit. Rübenzucker-Industrie, 25, 1054.

The calculations as given here are modified for application to juices.

In applying this method to other sugar-house products, using the normal weight, calculate as follows: First volume 100 cc.; second volume 200 cc.; multiply the second polariscope reading by 2 and subtract the product from the first reading; multiply the remainder by 2 and subtract the product from the first reading. This last remainder is the per cent of sucrose.

It is evident that this method demands extreme care in making the tests, since an error is multiplied.

W. D. Horne [1] recommends the use of dry subacetate of lead to eliminate the volume of precipitate error. The finely powdered lead salt is added to the solution after dilution to volume. Thorough mixing and filtration follow. If the lead salt has been added in just sufficient quantity for the clarification, there is no dilution of the solution and no precipitate error. All the precautions necessary in the use of the lead in solution as regards precipitation of reducing sugar, influence upon specific rotation, etc., must be observed with the dry-salt.

Horne's method has proven of great value in sugar analysis and in the storage of juice samples. The writer has stored a sample of raw-juice with it in a hot tropical country during a period of 10 days without perceptible deterioration. After a further period of five days there were slight signs of alteration. No more of the lead salt was used than was necessary for the clarification.

84. Influence of Subacetate of Lead and other Substances upon the Sugar and optically active Non-sugars in Cane Products.—*Sucrose.*—The rotatory power is not modified by subacetate of lead under the usual analytical conditions. In the presence of a very large excess of the lead salt, there is a slight diminution of the rotatory power; there is a decided diminution in alcoholic solution containing the lead salt.

The investigations of Bates and Blake, U. S. Bureau of Standards, [2] show that errors of importance in rotation are

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[1] Journal American Chemical Society, vol. 26, p. 186.
[2] Bulletin No. 3, p. 105.

caused by excessive amounts of subacetate of lead. An excess of 0.5 cc. causes a diminution of 0.1°; 1 cc. of 0.12°; 2 cc. of 0.11° and 3 cc. a diminution of 0.90° on the cane-sugar scale. The rotation reaches a minimum value when an excess of 1 cc. is present and returns to the initial value with 6 cc. in excess and continues to increase with the amount of lead solution added. A sugar polarizing 99.9° was used in these experiments.

Farnsteiner [1] made the following observations relative to the influence of certain inorganic salts: "With constant relation of sugar to water, the chlorides of barium, strontium, and calcium cause a decrease in the rotation, which continues to decrease as the salt is increased; calcium chloride causes a decrease, but when the salt reaches a maximum further addition causes an increase which finally exceeds that of the pure-sugar solution.

"If the relation of the sugar to that of the salt be kept constant, it is found that the addition of water causes in all cases an increase in the specific rotatory power, i.e., the action of the salts is lessened. The specific rotatory power is almost unaffected by varying the quantity of sugar with a constant relation between the salt and water. The chlorides of lithium, sodium, and potassium behave in a similar manner.

" An examination of the action of the same quantities of different salts shows that in the case of strontium, calcium, and magnesium the depression varies inversely with the molecular weight, and that the product of the two quantities is approximately a constant. Barium chloride does not act in the same manner, but the chlorides of the alkalis show a similar relation. The relation, however, only holds good within each group of chlorides and not for two salts belonging to different groups."

The rotatory power of sucrose in water or in alcohol solution is not modified by the presence of nitrates of sodium and potassium even when the quantity of the nitrate amounts to as much as 50 per cent of the sucrose (E. Gravier).

In his investigation of the influence of the lead precipitate,

[1] Berichte deut. chem. Gesell. 23, 3570; Journ. Chem. Soc., 60, 283.

Sachs [1] found that the presence of acetate of potassium very perceptibly diminished the rotation. The diminution was also noticeable with the sulphates of potassium and lead, but was not so marked with the corresponding sodium salts. Sachs also states that citrate of potassium, carbonate of sodium, and several other salts have an influence analogous to that of the acetates. The presence of free acetic acid reduces this influence in part. Sachs further states that the use of tannic acid in decolorizing solutions is very objectionable on account of the volume of the precipitate formed with the lead.

Dextrose.—The rotatory power of dextrose is not modified. or, if at all, but very slightly, by either the subacetate or neutral acetate of lead, under the analytical conditions See also Invert-sugar.

Levulose.—The rotatory power of levulose is very greatly diminished by the presence of subacetate of lead. Acetic acid added to acidity restores the rotation of the levulose (Gill in 1871, Spencer in 1885, Pellet). Levulose is partly precipitated as a lead salt in the presence of certain chlorides, in quantities greater or less, according to the relative proportions of the salts, lead, and levulose (Pellet, Edson). Basic acetate of lead precipitates levulose in part, when salts occur in the same solution with constituents of which basic acetate of lead forms insoluble combinations (Prinsen-Geerligs).

Invert-sugar, Dextrose, and Levulose.—In the presence of the salts formed in the decomposition of the subacetate of lead, dextrose, and levulose are precipitated in part (Pellet, Edson). The influence of the basic lead salt on the rotatory power of levulose (see Levulose) or the formation of levu'osate of lead of little optical activity gives undue prominence to the dextrose, which is not affected and results in a plus error. Increasing amounts of subacetate of lead added to invert-sugar solutions decrease the left rotation, and finally the rotation is to the right on account of that of the dextrose. C. H. Gill called attention to this error in the Journal of the Chemical Society, April, 1871, and in the early editions

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of this book, the author advised the use of aœtic acid to restore the rotatory power of the levulose.

Acetic acid slightly lowers the rotatory power of invert-sugar; hydrochloric acid has an opposite effect. Sodic acetate and sodic chloride increase the rotation (H. A. Weber and Wm. McPhersons).   Sulphuric and hydrochloric acids increase the rotation; oxalic acid has no effect.   The rotation increases as the quantity of the mineral acid is increased.   If the invert-sugar solution be diluted after warming with hydrochloric acid, it does not quickly reach the rotation corresponding to its dilution, which requires about twenty-four hours (Gube [1]).

Malic acid.—This acid is lævorotatory. The artificial malic acid is optically inactive. Malic acid is precipitated by subacetate of lead.

Pectine and Parapectine.—These substances are dextrorotatory and are both precipitated by subacetate of lead, and the second by normal acetate of lead.

Asparagine.—Not precipitable by subacetate of lead, but is rendered dextrorotatory instead of lævorotatory by the lead salt. In water solution and alkaline solution asparagine is lævorotatory; in acid solution, dextrorotatory.[2] Asparagine is insoluble in alcohol, and in the presence of acetic acid is inactive.[3] In neutral and alkaline solution asparagine is lævorotatory; in presence of a mineral acid, dextrorotatory; in the presence of acetic acid the rotation is diminished and with 10 molecules of the acid becomes 0°, and with additional acid is dextrorotatory (Degener). Asparagine is present in cane-juice, especially that from immature cane; it is changed to aspartic acid by the action of lime, and as a lime salt is found in molasses.[4]

Aspartic Acid.—From asparagine by the action of lime; the lime salt is soluble. In alkaline solutions, aspartates are lævorotatory and in acid solutions dextrorotatory. Aspartic acid is precipitated by subacetate of lead.

[1] Bulletin Assoc. Chimistes de France, 3, 131.

[2] Optical Rotation of Organic Substances, Landolt—Dr. Long's Eng. ed., 541.

[3] Champion and Pellet, *Compt. Rend.*, 82, 819.

[4] W. Maxwell, Bul. 38, 2d Series, La. Expt. Station, p. 1380.

85. Bone-black Error.—Bone-black or animal charcoal exercises an absorbent action on sugars. For this reason it is desirable to avoid using it in analytical work whenever possible. It is advised by different experimenters to add quantities ranging from 1 to 3 grams of powdered, dry bone-black to the half-normal weight of material in 100 cc. of solution; others advise the filtration of 50 cc. of the sugar solution through a small quantity of bone-black and the rejection of the filtrate, and then the filtration of sufficient for the observation.

In recent experiments the writer adopted the following method: Place a small quantity of bone-black, about 3 grams, in a small plain filter, selecting a rather slow filtering-paper. Add a volume of the solution equal to that of the char or just completely moisten the latter, and let this liquid filter off. After four or five similar filtrations, the filtrates from which are rejected, test the filtrates by a polariscopic observation and note whether the reading varies. Solutions must be protected from evaporation during the filtration. So soon as the reading is constant, showing no further absorption, record it as the required number. This method is very tedious, but apparently gives very satisfactory results when the coloring matter is not difficult to remove. If the color persists obstinately, it is preferable to filter the solution through the bone-black and reject the first half of the filtrate. The use of the nitrogen filled concentrated filament Mazda electric-lamp in polarizing will usually enable one to dispense with animal charcoal.

86. Influence of Temperature upon Polarizations. —The compensating type of polariscope can only give correct readings at the temperature at which it was standardized. The former standard temperature for these instruments was 17.5° C. and usually all the instruments made prior to about 1898 conformed to this standard. In 1897 the International Commission for Uniform Methods of Sugar Analysis adopted 26 grams as the normal weight and 100 true cc. at 20° C. as the corresponding volume. The instrument makers have conformed with this specification.

The rotation due to the quartz wedges increases with rise of temperature and that of sucrose decreases. Dr. H. W.

Wiley called the attention of the U. S. Treasury Department to the errors introduced into sugar polarizations by these conditions and prepared a table of corrections. The Treasury applies a temperature correction in raw-sugar testing based upon Wiley's observations.

Charles A. Browne [1] made a very full study of the influence of temperature in the polarization of raw-sugars and concluded that it is impossible to devise a simple reliable method of corrections for cane-sugars. In view of this conclusion, he has equipped his laboratory (New York Sugar Trade Laboratory) with constant temperature rooms in which all sugar solutions are prepared and polarized at 20° C. This arrangement obviates all question of corrections.

Brown states that the formula, $P^{20} = P^t[1 - 0.0003(t - 20)]$, in which P^{20} is the corrected polarization, P^t, the observed polarization, and t the temperature of the observation, may be applied without serious error to cane-sugar polarizing above 96° and that Wiley's table may also be used. Neither table nor formula are applicable to sugars of lower polarization. Few, if any sugar factories are equipped for polarizations under standard conditions.

Obviously certain precautions can, and should, be observed to reduce errors: The laboratory and polariscope room should be well ventilated and of the same temperature. The polariscope should not be in the vicinity of a heated wall or the laboratory-ovens. The solutions should be prepared and polarized at room temperature. Composite samples of s gar, used in part as a basis of the technical reports (run reports), should be polarized at a time of low temperature in tropical laboratories rather than in the heat of the afternoon.

No temperature correction is required for the instrument itself when of the Laurent type using monochromatic ligl t.

87. Limits of Accuracy in Saccharimetric Analysis.[2]—Dr. C. A. Browne notes twelve errors that may

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[1] Handbook of Sugar Analysis, pp. 255–262.

[2] Dr. C. A. Browne, N. Y. Sugar Trade Lab., read a paper with this title before the New Orleans Section of the Am. Chem. Soc., Nov. 20, 1914. The comments and conclusions in this paragraph are abstracted from this paper, including the summing up of the residual error.

enter into sugar analysis. While these refer specifically to sugar-testing they apply also to a considerable extent in all other analyses:

1. Loss of moisture during mixing.
2. Loss of moisture during weighing.
3. Error in normal weights.
4. Volume of precipitate in clarification.
5. Precipitation of levulose.
6. Error in capacity of flasks.
7. Imperfect mixing of contents of flask.
8. Evaporation during filtering.
9. Error in length of polariscope tubes.
10. Omission of bichromate cell.
11. Variations in temperature.
12. Defects in scales of saccharimeters.

The errors 3, 6, 9 and 12 are in general mutually compensating and with careful management do not appear in the results. Since flasks and tubes may be selected that vary but slightly on each side of the correct numbers, the errors disappear in the averages of duplicate tests. The weights may easily be kept within the limits of accuracy of the balance. The scales of the polariscope may be checked near the important points with accurate standard quartz plates and corrections be made. Other points and in fact all parts of the scale may be checked with the Schmidt & Haensch control-tube, Fig. 29. Dr. Browne estimates that the following plus errors may enter in careless work. These are numbered as in the previous list:

Error due to:	Sugar Degrees.
1. Mixing on paper	+0.05
2. Evaporation during weighing	+0.02
4. Volume of precipitate in clarification	+0.18
5. Precipitation of levulose	+0.03
7. Imperfect mixing of the contents of the flask	+0.05
8. Evaporation during filtering	+0.04
10. Omission of the bichromate cell	+0.07
11. Temperature variation from the standard	+0.04
Total error	+0.48

The last four errors amounting to 0.20° are preventable and the first four may be reduced. The final residual error in careful work should not exceed +0.12 as follows:

Error due to:	Sugar Degrees.
1. Evaporation in mixing................	+0.010
2. Evaporation in weighing.............	+0.005
4. Volume of precipitate................	+0.090
5. Precipitation of levulose.............	+0.015
Total error....................	+0.120

There are other sources of error that have already been considered in the previous pages of this work, such as those introduced by pressure upon the cover-glasses, pressure upon or the wiping of the standardized quartz-plates, preparation of the solution at a different temperature from that of the observation, etc. Such errors are entirely avoidable.

The use of alumina cream or the normal acetate of lead in the clarification instead of the basic acetate, when the material will permit, practically eliminates the levulose error. Horne's dry-lead method removes, or nearly so, the volume of precipitate error. It is possible that both these errors would be reduced by the use of dried acetate of lead in clarifying, where conditions of color will admit.

The temperature error is one of the most important with which the tropical chemist must deal. This may amount to −0.5° in extreme cases. Since a constant temperature laboratory is an improbable addition to a sugar-house, the only defense against this error lies in making important tests early in the morning during the low-temperature period, or in the use of arbitrary temperature corrections.

CHEMICAL METHODS IN SUGAR ANALYSIS.

88. Analytical Methods in General.—The chemical methods of sugar analysis depend upon the property that dextrose and levulose have, in alkaline solutions, of reducing cupric oxide to cuprous oxide. Under like conditions, the amount of copper reduced is in proportion to the quantity of the sugar present. In the table, page 458, the behavior of many of the carbohydrate bodies, with alkaline copper reagent, is given.

In the chemical methods, it is very necessary to comply strictly with the directions for the analysis, since a change in the conditions renders the tables for the calculations useless. The volumetric methods require less time and labor, but are not so accurate as the gravimetric. Volumetric methods are described in page 247.

In selecting the reduction method it must be taken into account that there is a slight reduction of copper by sucrose in the presence of invert-sugar.

89. Determination of Sucrose.—Dissolve a weighed quantity of the material, equivalent to 10 grams of invert-sugar in water in a flask and dilute the solution to 75 cc. Add 5 cc. of concentrated hydrochloric acid and mix the contents of the flask by a circular motion and place it on a water-bath heated to 70° C. Raise the temperature of the solution in the flask to 67°–70° C. in from two and a half to three minutes and maintain as nearly a temperature of 69° C. as possible for seven to seven and a half minutes longer, making a total time of heating of ten minutes. Remove the flask and plunge it into cold water to rapidly cool its contents. This part of the process is termed the inversion, and is for the purpose of converting the sucrose into invert-sugar, i.e., dextrose and levulose. This inversion may be accomplished without heat by letting the acid solution stand during twenty-four hours at the room temperature.

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After completing the inversion transfer the solution to a liter-flask, dilute it and then almost neutralize it with dilute caustic soda solution and complete the volume to 1000 cc.

The solution contains dextrose and levulose and should be analyzed by the following method of Meissl and Wein: Measure 25 cc. of solution (A) and 25 cc, of solution (B), Soxhlet's solution, **297,** page 416, into a 250-cc. beaker, add 50 cc. of the sugar solution and boil two minutes, using the naked flame of the lamp.

Collect the cuprous oxide and determine the copper in it by one of the methods in **118,** page 235. Ascertain the weight of the invert-sugar from the number of milligrams of copper reduced, using the table on pages 189, 190, and multiply this weight by 0.95 to reduce it to terms of the weight of sucrose in the quantity of the material used. This multiplication is necessary since sucrose yields invert-sugar, on inversion, in the ratio of 100:95.

If the material contains glucose (reducing-sugar) in addition to sucrose, determine the reduction before inversion by **118,** and after inversion by the method just described for invert-sugar. Calculate the percentage of sucrose as follows:

Per cent invert-sugar after inversion − glucose in the material × 0.95 = the required per cent sucrose.

90. Determination of Glucose (Reducing-sugar).— The method to be selected for glucose depends upon the quantity of this substance in the material and also whether sucrose is present.

If no sucrose is present, the method described in the preceding paragraph is to be used. If both sucrose and glucose are present, one of the methods on page 235 should be employed.

TABLE FOR THE ESTIMATION OF INVERT-SUGAR.

(Meissl and Wein.)

Copper.	Invert-Sugar.	Copper.	Invert-Sugar.	Copper.	Invert-Sugar.	Copper.	Invert-Sugar.	Copper.	Invert-Sugar.
Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.
90	46.9	135	70.8	180	95.2	225	120.4	270	146.1
91	47.4	136	71.3	181	95.7	226	120.9	271	146.7
92	47.9	137	71.9	182	96.2	227	121.5	272	147.2
93	48.4	138	72.4	183	96.8	228	122.1	273	147.8
94	48.9	139	72.9	184	97.3	229	122.6	274	148.4
95	49.5	140	73.5	185	97.8	230	123.2	275	149.0
96	50.0	141	74.0	186	98.4	231	123.8	276	149.5
97	50.5	142	74.5	187	99.0	232	124.3	277	150.1
98	51.1	143	75.1	188	99.5	233	124.9	278	150.7
99	51.6	144	75.6	189	100.1	234	125.5	279	151.3
100	52.1	145	76.1	190	100.6	235	126.0	280	151.9
101	52.7	146	76.7	191	101.2	236	126.6	281	152.5
102	53.2	147	77.2	192	101.7	237	127.2	282	153.1
103	53.7	148	77.8	193	102.3	238	127.8	283	153.7
104	54.3	149	78.3	194	102.9	239	128.3	284	154.3
105	54.8	150	78.9	195	103.4	240	128.9	285	154.9
106	55.3	151	79.4	196	104.0	241	129.5	286	155.5
107	55.9	152	80.0	197	104.6	242	130.0	287	156.1
108	56.4	153	80.5	198	105.1	243	130.6	288	156.7
109	56.9	154	81.0	199	105.7	244	131.2	289	157.2
110	57.5	155	81.6	200	106.3	245	131.8	290	157.8
111	58.0	156	82.1	201	106.8	246	132.3	291	158.4
112	58.5	157	82.7	202	107.4	247	132.9	292	159.0
113	59.1	158	83.2	203	107.9	248	133.5	293	159.6
114	59.6	159	83.8	204	108.5	249	134.1	294	160.2
115	60.1	160	84.3	205	109.1	250	134.6	295	160.8
116	60.7	161	84.8	206	109.6	251	135.2	296	161.4
117	61.2	162	85.4	207	110.2	252	135.8	297	162.0
118	61.7	163	85.9	208	110.8	253	136.3	298	162.6
119	62.3	164	86.5	209	111.3	254	136.9	299	163.2
120	62.8	165	87.0	210	111.9	255	137.5	300	163.8
121	63.3	166	87.6	211	112.5	256	138.1	301	164.4
122	63.9	167	88.1	212	113.0	257	138.6	302	165.0
123	64.4	168	88.6	213	113.6	258	139.2	303	165.6
124	64.9	169	89.2	214	114.2	259	139.8	304	166.2
125	65.5	170	89.7	215	114.7	260	140.4	305	166.8
126	66.0	171	90.3	216	115.3	261	140.9	306	167.3
127	66.5	172	90.8	217	115.8	262	141.5	307	167.9
128	67.1	173	91.4	218	116.4	263	142.1	308	168.5
129	67.6	174	91.9	219	117.0	264	142.7	309	169.1
130	68.1	175	92.4	220	117.5	265	143.2	310	169.7
131	68.7	176	93.0	221	118.1	266	143.8	311	170.3
132	69.2	177	93.5	222	118.7	267	144.4	312	170.9
133	69.7	178	94.1	223	119.2	268	144.9	313	171.5
134	70.3	179	94.6	224	119.8	269	145.5	314	172.1

TABLE FOR THE ESTIMATION OF INVERT-SUGAR.—*Continued.*

Copper.	Invert-Sugar.	Copper.	Invert-Sugar.	Copper.	Invert-Sugar.	Copper.	Invert-Sugar.	Copper.	Invert-Sugar.
Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.
315	172.7	340	187.8	365	203.0	390	218.7	415	235.7
316	173.3	341	188.4	366	203.6	391	219.3	416	236.4
317	173.9	342	189.0	367	204.2	392	219.9	417	237.1
318	174.5	343	189.6	368	204.8	393	220.5	418	237.8
319	175.1	344	190.2	369	205.5	394	221.2	419	238.5
320	175.6	345	190.8	370	206.1	395	221.8	420	239.2
321	176.2	346	191.4	371	206.7	396	222.4	421	239.9
322	176.8	347	192.0	372	207.3	397	223.1	422	240.6
323	177.4	348	192.6	373	208.0	398	223.7	423	241.3
324	178.0	349	193.2	374	208.6	399	224.3	424	242.0
325	178.6	350	193.8	375	209.2	400	224.9	425	242.7
326	179.2	351	194.4	376	209.9	401	225.7	426	243.4
327	179.8	352	195.0	377	210.5	402	226.4	427	244.1
328	180.4	353	195.6	378	211.1	403	227.1	428	244.9
329	181.0	354	196.2	379	211.7	404	227.8	429	245.6
330	181.6	355	196.8	380	212.4	405	228.6		
331	182.2	356	197.4	381	213.0	406	229.3		
332	182.8	357	198.0	382	213.6	407	230.0		
333	183.5	358	198.6	383	214.3	408	230.7		
334	184.1	359	199.2	384	214.9	409	231.4		
335	184.7	360	199.8	385	215.5	410	232.1		
336	185.4	361	200.4	386	216.1	411	232.8		
337	186.0	362	201.1	387	216.8	412	233.5		
338	186.6	363	201.7	388	217.4	413	234.3		
339	187.2	364	202.3	389	218.0	414	235.0		

DENSITY DETERMINATIONS.

APPARATUS AND METHODS.

91. General Remarks.—The expression "density" is very commonly used in the sugar industry synonymously with "specific gravity." Sugar chemists also frequently term the degree Brix or the degree Baumé the "density" of the solution. This use of the word density is not strictly correct, but it is sanctioned by usage and the word will be used in this sense in this book for brevity and convenience. The graduations on hydrometers used in sugar-work are termed "degrees."

92. Degree Brix or Balling.—This system of hydrometer graduation was devised by Balling; the data were afterwards recalculated and checked by Brix. This hydrometer is known by both names in Germany, but the name "Brix" is used almost exclusively in America. The degree Brix is the percentage by weight of sucrose in a pure sugar solution. In commercial sugar analysis it is customary to consider the degree Brix as the percentage of solid matter, or the total solids, dissolved in a liquid. It is this feature of the Brix hydrometer, or spindle, as these instruments are commonly called, which renders it more convenient than the Baumé instrument in sugar-house work.

The degree Brix, as determined by floating a spindle in a sugar solution, is termed the apparent degree Brix. The percentage of total solid matter in a sugar solution as determined by drying in an oven is often called the true degree Brix. Except when qualified by the word "true," the apparent degree Brix is understood to be meant. This spindle is often termed Balling, and the readings on its scale degrees Balling.

The French use two modifications of this instrument, the Brix-Dupont and the Brix-Vivien spindles. The Brix-

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Dupont hydrometer reads 0° in distilled water at 15° C.,
whereas the Brix spindle reads 0° at 17½° C., or according
to the standard adopted by the International Congress of
Chemistry, at 20° C. Both of these hydrometers indicate
percentages by weight. The Brix-Vivien hydrometer indi-
cates the percentage of sugar in a solution at 15° C. in
terms of the weight and volume, i.e., grams of sugar in
100 cc. of solution.

It may be well to state that the Brix spindle and its
modifications indicate percentages of sucrose in water
solutions containing only the pure sugar.

93. Degree Baumé. — The Baumé (also spelled
Beaumé) scale has no convenient relation with the per-
centage composition of any sugar-house product. The
point to which the Baumé hydrometer sinks in distilled
water at the standard temperature is marked zero; the
corresponding point in pure sulphuric acid of 1.8427 specific
gravity is marked 66°. Baumé spindles are also graduated
for densities below zero, but the range of from 0° to 50°
is all that is required in the sugar industry.

Gerlach and later Mategczek and Scheibler recalculated,
the values of the graduations of the Baumé scale. The
recalculated numbers are termed the "new" or "corrected"
degrees Baumé and are those given in the table, page 450.

The Baumé scale was at one time used almost exclusively
in the sugar industry, but at present chemists usually prefer
the Brix scale. Planters and sugar-makers still use the
Baumé scale. .

94. Hydrometers or Spindles.—These instruments
are frequently termed "saccharometers" when specially
graduated for use in the sugar industry.

A high-grade Brix hydrometer is shown in Fig. 46. This
instrument is provided with a thermometer. Instruments
for ordinary work, in the factory, are made of metal or of
glass, and without the thermometer. In America and Ger-
many the standard temperature for the graduation of these
instruments has been, until recently, 17½° C. The present
standard adopted by the International Congress of Applied
Chemistry is 20° C., though this is not yet in general
use. For temperatures varying from these standards.
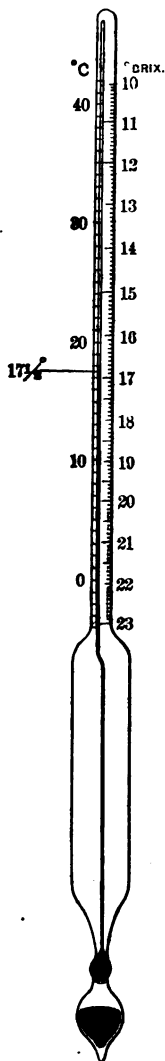
corrections must be applied to the readings.

Hydrometers whose normal or standard temperature is $17\frac{1}{2}°$ C., when floated in distilled water at this temperature, read 0°, and the corresponding specific gravity of the water is 1.0000. In other words, the weight of a volume of the sugar solution at $17\frac{1}{2}°$ C. is referred to the weight of the same volume of water at $17\frac{1}{2}°$ C. The table on page 450 is constructed for this normal temperature, $17\frac{1}{2}°$ C.

Hydrometers whose normal or standard temperature is 20° C., as specified by the International Congress of Applied Chemistry, when floated in water at this temperature, read 0°, and the corresponding specific gravity is 0.998234. The specific gravities of the solutions, corresponding with the degrees Brix, are given in the table, page 477.
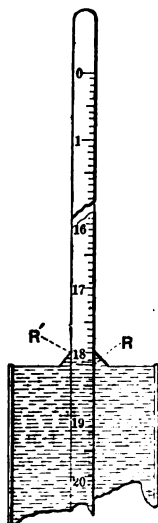
In using the hydrometer, it is floated in the sugar solution and the reading on the scale is made at the point R, not R', of Fig. 47. The point R is at the level of the surface of the liquid and is selected for the reading, since R' varies with the viscosity of the solution. It is often necessary in dark solutions to estimate the position of the point R. The reading of the scale is not made until after allowing sufficient time for the hydrometer to become of the same

Fig. 46.   Fig. 47.

temperature as the solution. If the temperature of the liquid varies from the normal temperature for which the hydrometer is graduated, the observed reading of the scale must be corrected. For instruments whose normal temperature is 17½° C., the corrections given in Gerlach's table, page 489, should be used. For instruments that are graduated at 20° C., in conformity with the specification of the International Commission for Uniform Methods, the table of corrections cn pages 490 and 491 should be used. It is necessary in accurate work to use the hydrometer at near its normal temperature. The correction tables should be used with caution and only for approximate results when the temperature differs much from the normal.

Hydrometers are also made with the corrections printed on the paper with the thermometric degrees, the height of the mercury column indicating the correction to be applied.

The writer recommends the type of hydrometer shown in Fig. 46, the thermometer being included. No difficulty is experienced in reading the temperature, even in molasses solutions, since at most the instrument need be lifted only until the mercury column emerges. The stems should be of very small diameter, that the graduation may be open and easily read. A range of 10° Brix per 5 to 5.5 inches of stem is advised.

Hydrometers should be tested from time to time, employing standardized solutions of pure sucrose, at approximately the temperature at which the instrument was graduated. The hydrometer-jar or cylinder should be wide, so that the spindle may float perfectly freely.

95. The Westphal Balance[1].—The principle of this balance, Fig. 48, may be briefly stated as follows: A glass bob is so adjusted as to be capable of displacing a given number of grams, five for instance, of distilled water at a given temperature when wholly immersed in the liquid and suspended by a fine platinum wire. The bobs may be graduated for any temperature; but for sugar-work 17½° C. is most convenient, since this is the temperature usually employed in preparing specific-gravity tables. For accurate work the temperature of the solution whose specific gravity is to be determined should be exactly that for which the

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[1] Adapted from Bulletin 13, Chem. Div., U. S. Dept. Agri.; also illustration.

bob was graduated. The balance is provided with several riders or weights. Two of these riders, 1 and 2, are each exactly the weight of the water displaced by the bob at the standard temperature, $17\frac{1}{2}°$ C. The other riders, 3, 4, and 5, are respectively one-tenth, one-hundredth, and one-thousandth
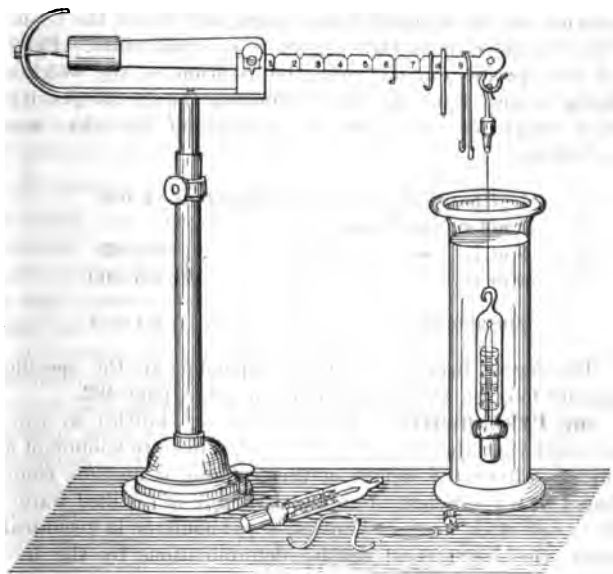
Fig. 48.

the weight of the first mentioned. When the weight 1 is hung on the hook at the end of the beam and the bob immersed in distilled water at $17\frac{1}{2}°$ C., the balance should be in equilibrium, the weight having the value 1.000 in this position. In case the balance is not in equilibrium under these conditions, provided the bob has been correctly graduated, suspend this latter from the hook and turn the adjusting-screw until the pointers are exactly opposite one another. The weights 2, 3, 4, and 5 are placed on the beam in addition to 1 for liquids heavier than water, and have the values .1, .01, .001, and .0001, respectively, when placed on the corre-

sponding graduations of the beam, and for other graduations .300, .030, .003, .0003, etc. Each rider is provided with a hook from which additional weights may be suspended in case of more than one falling upon the same graduation.

The method of using the balance is as follows: Suspend the bob of the balance as described above in the solution, at the standard temperature, and weight the beam with the riders until the balance is in equilibrium. Read off the specific gravity from the position of the weights on the beam. Example: In determining the specific gravity of a sample of cane juice the position of the riders was as follows:

1 at point of suspension of the bob = 1.000
2 not on the beam.
3 at 7. . . .⌐. . . . . = 0.07
4 at 9. . . . . = 0.009

Specific gravity. . . . . = 1.079

The degree Brix or Baumé corresponding to the specific gravity may be ascertained from the table, page 482.

96. Pyknometers. — Pyknometers are bottles so constructed that they may be filled with a definite volume of a liquid. Given the weight of this volume, it may be compared with the weight of an equal volume of distilled water. It is not often necessary to use a pyknometer in technical work, the more rapid density determinations by the hydrometer being usually sufficiently accurate.

Pyknometers are made in a great variety of forms. One of the most convenient of these is shown in Fig. 49. The side tube provides an outlet for the excess of liquid when the stopper, a fine thermometer, is put in place, also for the overflow, as the temperature of the liquid rises. The bottle should be filled with the liquid cooled to a temperature lower than that at which the density is to be determined. As the temperature rises to the desired point, the liquid expands and the excess is blotted with paper at the side tube. At the required temperature the cap is placed in position and receives any further liquid that may be expelled, as the temperature rises to that of the work-room.

There is a minute opening in the top of the cap for the escape of the air.

It is convenient in sugar-work to determine the specific gravity at $17\frac{1}{2}°$ C., the solution at this temperature being compared with the weight of an equal volume of water at $17\frac{1}{2}°$ C. The International Committee on Uniform Methods of Analysis adopted $20°$ C. as the standard for the solution, referring it to water at $4°$ C., the temperature of its maximum density. The standard used is indicated as follows: $\frac{17\frac{1}{2}°}{17\frac{1}{2}°}$ C. $= 1.07956$, meaning that the temperature of the solution and that of the water were each $17\frac{1}{2}°$. The number above the line is that of the solution, and that below the line, that of the water.

By means of the pyknometer, described in this article, the weighings can readily be made of the liquid held by the specific gravity bottle at $17\frac{1}{2}°$ C. The specific-gravity under these conditions is calculated by dividing the weight of the solution by the weight of an equal volume of water. In both cases the bottle is filled at $17\frac{1}{2}°$ C.

FIG. 49.

In determining the specific gravity at the standard $\frac{20°}{4°}$ C., the process is more complicated, since the expansion of the glass pyknometer and the air density must be taken into account. The following description of the calculations, also the table, are from Landolt's work.[1] The pyknometer is first filled with recently boiled and cooled distilled water, and is weighed. The temperature and weight are noted. The weight is the apparent mass of the water in the air, a constant for the pyknometer at the temperature, t_0, at which it was filled and should therefore be determined with great care.

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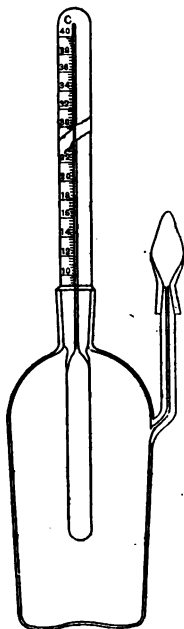
[1] Optischem Drehungsvermögen.

The calculations are made by the following formula, in which the letters have the values indicated below:

$$d_t = \frac{FQ_0}{W_0} + \frac{FQ_0}{W_0}. \quad 3\beta(t_0 - t - \frac{\lambda(F - W_0)}{W_0}),$$

W_0, the apparent mass of the water in the air at the temperature t_0;

F, the apparent mass of the sugar solution in the air at the temperature t;

Q, specific gravity of water at the temperature t_0;

$3\beta = 0.000024$, the coefficient of cubical expansion of glass;

$\lambda = 0.0012$, the air density;

$d_t =$ specific gravity of the solution of the sugar at the temperature t referred to water at 4° C.

The first factor of the formula is the uncorrected specific gravity, the second factor corrects the specific gravity for temperature and the third factor is for the reduction to weights in vacuo.

The value of Q may be taken from Landolt's table at the end of this article. If the difference between t and t_0 is small, a mean value, 0.000024, may be used for 3β.

SPECIFIC GRAVITY OF WATER AT VARIOUS TEMPERATURES.
(From Landolt's Optischem Drehungsvermögen.)

t_0	Q_0	t_0	Q_0	t_0	Q_0	t_0	Q_0
0	0.999874	17.7	0.998683	20.0	0.998235	22.4	0.997709
1	930	8	664	1	214	5	685
2	970	9	646	2	193	6	662
3	993	18.0	628	3	172	7	639
4	1.000000	1	609	4	151	8	615
5	0.999992	2	590	5	130	9	592
6	969	3	571	6	109	23	568
7	931	4	552	7	087	24	326
8	878	5	533	8	066	25	073
9	812	6	514	9	044	26	0.996811
10	731	7	495	21.0	023	27	540
11	637	8	476	1	001	28	260
12	530	9	456	2	0.997979	29	0.995971
13	410	19.0	437	3	957	30	674
14	277	1	417	4	935	31	368
15	132	2	397	5	913		
16	0.998976	3	377	6	890		
17.0	808	4	357	7	868		
1	790	5	337	8	846		
2	772	6	317	9	823		
3	755	7	296	22.0	800		
4	737	8	276	1	778		
5	719	9	255	2	755		
6	701			3	732		

GENERAL ANALYTICAL WORK.

97. General Remarks on Sampling and Averaging.
—One of the most difficult, and often unsatisfactory, problems for the cane-sugar chemist is that of securing representative samples of the juices and various products at the different stages of the manufacture. If a sample does not strictly represent the average composition of the material, the analytical work will usually be of but little if any value.

In order that the samples may be representative they must be drawn continuously in proportion to the quantity of the material. Or, they must be secured at intervals, drawing a definite quantity in each sample, from a measured or weighed quantity of the material, the size of the sample always bearing the same relation to the amount of material sampled. This second method is the one usually practiced and is termed sampling by aliquot parts.

The importance of a proper method of sampling is illustrated by the following example: Given four lots of sirup A, B, C, and D from which an average sample is to be drawn. Let $A = 1000$, $B = 800$, $C = 500$, and $D = 200$, and let each lot differ from the others in analysis. Manifestly a mixture of equal parts of sirup from these lots would not be a true average sample, but a mixture of 10 parts of A, 8 of B, 5 of C, and 2 parts of D would represent the average composition of the sirup.

In averaging the analyses of the various materials in a cane-sugar house, it is advisable to use the weights rather than the volume. Thus the weights of the juice, the sucrose, and the apparent solids (Brix) should be recorded daily and at the end of a "run" or period the sum of the daily

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weights of sucrose divided by the weight of the juice and the quotient multiplied by 100, will give the mean per cent of sucrose in the juice and so on. Similarly the analyses of the sugars, and, so far as possible, those of the other products should be averaged.

For the general laboratory data, the author prefers to collect daily one composite sample of the juices and each product. This is advisable since the quantity of material represented by the analyses is usually known or estimated daily, thus giving the analytical work a definite value.

98. Sampling the Cane in the Field.—It is practically impossible to secure a moderate-sized sample of sugarcane that will be even fairly representative of that of a field. The best the chemist may hope to accomplish, under favorable conditions, is to obtain a sample that will in a very general way indicate the condition of the cane. The difficulty in sampling is due to the great variations in the analysis of canes from the same stool and also from various parts of even a small field. Frequently in a large factory, receiving cane from many fields, the daily average analyses will differ but little from day to day whereas single analyses may vary widely from the average.

In sampling cut cane a few stalks should be selected from every second or third row, crossing the field one or more times, according to its size, in sampling. The large sample, after mixing the canes, should be reduced by subsampling to one of convenient size for the laboratory. This method is frequently impracticable, since the carts often follow close behind the cutters.

It is even more difficult to sample standing cane, since the field is an almost impenetrable jungle. In this case a few entire stools of cane should be secured from various parts of the fields, but not from near ditches or headlands, and these canes should be reduced to a convenient number, after mixing them thoroughly.

Perhaps the best method of sampling the whole cane is to await its arrival at the factory, then grind several cart- or car-loads apart from other cane, and analyze the juice.

99. Sampling the Cane at the Diffusion-battery.— The cane-chips may be sampled with considerable accuracy

at the diffusion-battery. A handful of the cuttings or chips should be withdrawn shortly after they begin to fall into the diffuser, and a second handful when the diffuser is about half filled. These samples should be stored in a clean covered metal or agate-ware pail. The samples drawn in this way should be taken to the laboratory at frequent intervals and be ground in the small mill. The milling should be made very heavy by repassing the bagasse through the mill. The juice samples should be composited, the small samples being drawn in proportion to the number of diffusers.

Pellet [1] recommends the storage of the fresh chips during a period of twelve hours, by placing an open bottle containing concentrated ammonia in the covered sample-pail or box.

100. Sampling Bagasse and Exhausted Diffusion-chips.—To a certain extent the bagasse presents the same sampling difficulties as the whole cane. The bagasse, however, is more or less well mixed in its passage through the mills and irregularities may be overcome by sampling across the conveyor.

Samples of bagasse should include all of that on a section of the bagasse-carrier, its entire width. On reaching the laboratory the sample should be quickly and thoroughly mixed and sub-sampled. The small sample may be analyzed immediately or stored six hours in a closed box in the presence of formaldehyde. A sponge should be saturated with the preservative and be attached to the inside of the box-cover.

In diffusion work, the exhausted chips are sampled by removing a handful from each diffuser as they are discharged. These small samples should be stored in a covered vessel, with provision at the bottom for drainage. At frequent intervals the composite samples so formed should be analyzed and the analyses weighted, in calculating the day's average, according to the number of diffusers.

101. Sampling the Juice.—When saturation or imbibition is practiced it is necessary to secure two samples of the mill-juice, one from the first mill and the second from all the

[1] Bulletin Assoc. des Chimistes, XXII, 922.

mills. It is preferable to draw the first of these samples from the juice canal of the crusher when there is liability of water from the mill-bearings mixing with the juice and in any event, it is usually advisable to sample at this point. The degree Brix of this first sample is used as a basis in calculating the so-called normal juice or undiluted juice, from the analysis of the mixed juices from the train of mills. The degrees Brix of the two samples are also used in calculating the dilution of the mixed juice due to maceration or leakage of water from the mill-journals.

Special sampling is necessary in determining the factor or coefficient to be applied in reducing the degree Brix of the crusher or first mill and crusher-juice, to terms of the normal juice that would be yielded in milling of equal efficiency without maceration water. This factor should be determined a sufficient number of times in the season to note its variations with cane and milling conditions. The juices from the crusher (or crusher and first mill) and that from the entire system are separately sampled. The sampling should be by automatic devices and should be continuous for an hour or longer. The first sample is of relatively high degree Brix, sucrose content and purity, due to the comparatively moderate pressure applied in crushing the cane. The degree Brix of the second sample is lower than that of the first on account of the very heavy crushing by the mills which extracts the rind-juice and many of the impurities of the cane. The factor is the relation between the degrees Brix of the two samples. The following example illustrates the calculation and use of the factor: Brix of the two samples, respectively, $20°$ and $19.7°$; factor $= 19.7 \div 20 = 0.985$. Brix of the mixed-juices in regular milling, 19.6, then $19.6 \times 0.985 = 19.3$, the degree Brix of the normal or undiluted juice.

The juice should be sampled automatically and in proportion to that extracted. The milling is usually very uniform under good conditions of equipment and operation, hence samplers may be operated by some part of the mill mechanism, preferably a roll-shaft. Certain types of samplers may be driven by a reciprocating or other part of the juice-pump.

The Calumet is an efficient type of samplers (Fig. 50).

It was devised at the Calumet Plantation, Louisiana.   The Calumet sampler shown in the figure was designed by the writer to draw juice from the crusher canal, and is now used in several large factories.   A modified type is necessary for sampling juice under pressure in pipe-lines.

The construction of the Calumet sampler is shown in the sectional scale-drawing, with the device bolted to the crusher-canal.   A hole is bored through the plunger, near the end, to receive the sample.   A lip or projection closes the lower
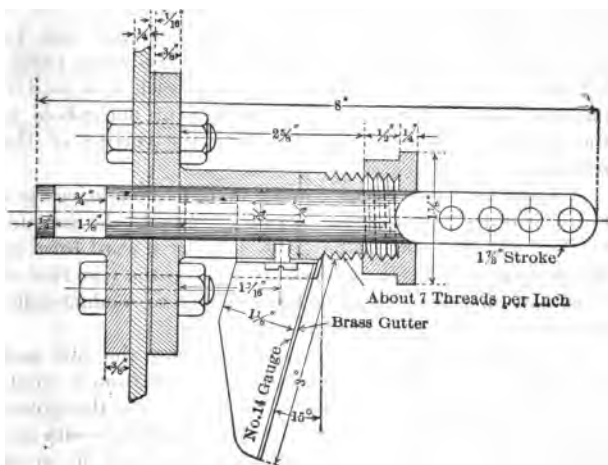
FIG. 50.

side of the hole while filling.   The plunger clears the trash from this projection at each stroke it makes.   When the plunger is withdrawn it discharges the sample through the lower end of the hole into the gutter.   A gland is provided to prevent leakage of juice.

The Calumet sampler for drawing juice from a pipe-line is of somewhat different construction.   The plunger should be about 1 inch in diameter and have a stroke of about 3 inches.   A juice cavity about $\frac{1}{2}$ inch in diameter is drilled longitudinally into the end of the plunger and is fitted with

a screw for adjusting the size of the cavity and consequently of the sample. A $\frac{3}{16}$ inch hole is drilled at right angles to the cavity and through it. Corresponding holes are drilled through the pump barrel for the inlet of air and the discharge of the sample from the plunger. Two rings of packing, controlled by a follower and packing-ring, are placed around the plunger, one at the outer end of the barrel and the other between the juice-inlet and outlet. There should be an oval opening in the packing-ring where it passes the juice-outlet, to admit of adjustment. The barrel of the sampler is screwed into the pipe from which the juice is to be drawn and is clamped into place with a locknut. This sampler may be operated from a reciprocating part of the juice-pump, reducing the speed, if need be, by a mechanism such as is used in pumping oil to a bearing. The vertical- or outlet-hole in the plunger is made small to reduce the cutting of the packing.

A device that may be used under favorable conditions is a heavy wire leading from the stream of juice to the sample-bottle. The wire should be given a sharp upward turn at the delivery point. It is necessary to keep the wire free of trash and further it should be large enough to conduct sufficient juice to minimize the evaporation error.

An undershot water-wheel, just dipping into the juice and driven by the current, may be used to sample from a canal. The axle of the wheel should be hollow and a few of the spokes should be tubular and communicate through the axle with the sample jar. The hollow spokes should terminate in small spoons which serve to take up a little of the juice and deliver it through the spokes and axle to the jar.

Coombs' drip sampler, Fig. 51, may be used if the juice is thoroughly strained. As is shown in the figure, a small stream of juice or other liquid is led through a glass T-tube and by properly adjusting the side branch of the tube a small stream of liquid is diverted through it to the sample jar.

Samples may be drawn from the discharge-pipe of a direct acting pump by means of a spring-controlled relief-valve. The valve should be adjusted to open at the moment of highest pressure at each pump stroke.

The difficulty with most of these samplers, except the Calumet, is their liability to clog, tendency to foul, uncertainty as to their sampling in proportion to the quantity of liquid passing them and the probability of not drawing an average sample under certain conditions, *e.g.* when drawing from a canal into which the juices from several mills flow. The Calumet sampler necessarily draws a correct sample when it is connected with the discharge line from a pump and is operated by the latter. When this sampler is connected with the canal leading from the crusher its sample is from only a part of the juice, but it is usually a very good approximation of a representative sample. Almost all mechanical samplers are superior to hand and drip samplers.

It is often necessary in sampling the mixed juices to draw a small measuring-cupful of juice at regular intervals

A.—$\frac{1}{2}$ TO $\frac{5}{8}$ INCH VALVE.
B.—STRONG RUBBER TUBE CONNECTING PIPE LEADING FROM "A" WITH
C,— A GLASS T-TUBE $\frac{3}{8}$ TO $\frac{1}{2}$ INCHES INSIDE DIAMETER.
D,— SHORT ARM OF T, FROM WHICH THE SAMPLE IS TO BE LED INTO AN APPROPRIATE RECEIVER.
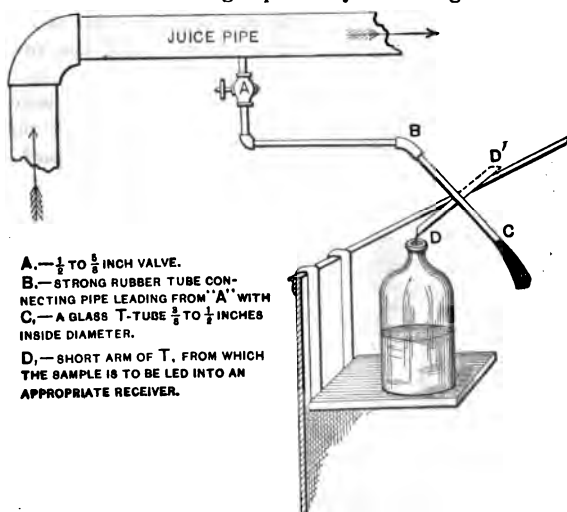
FIG. 51.

and with these form a composite sample. If the defecation system is used and the defecators are large, two small measured samples should be drawn when filling each tank; but if the defecators are small one sample will suffice. If the

juice flows into large lining-tanks, as in the Deming and similar processes, one or more small samples should be drawn as the tank is filling, one, for example, when the tank has three or four feet of juice in it, and a second when it is nearly filled.

Fig. 52.

If the juice is first pumped into small measuring-tanks, from which it flows to the liming-tanks, or defecators, the sample may be drawn by the Horsin-Déon or a similar automatic sampler as described below for diffusion work.

Duplicate samples should be drawn, one for the density determination and the other for the polarization.

Methods for the preservation of the samples of juice and observations in regard to them are given farther on in page 207.

102. Sampling Diffusion-juice.—The diffusion process requires the measurement of the juice, drawn from each diffuser, in a small measuring-tank. This measurement facilitates the automatic drawing of the juice sample by means of the Horsin-Déon sampler, Fig. 52.

This apparatus consists of a three-way cock for connecting a small stand-pipe alternately with the measuring-tank and the sample-bottle and is operated by a suitable float.

The sampler is placed inside the measuring-tank. It is so arranged that the sample of juice drawn is proportionate
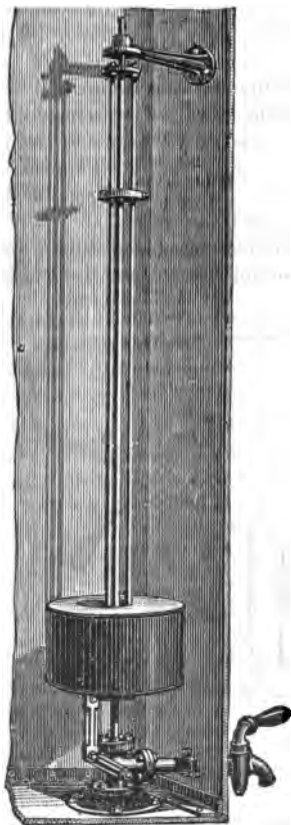
to the quantity of juice in the tank. The discharge-pipe from the battery should enter the measuring-tank from the bottom. The inlet to the sampler should be directly over the inlet from the battery, if practicable projecting a short distance into the pipe. If this precaution is not observed, the sample may not be representative of the tankful of juice.

103. Care of Samplers. Preservation of Samples.—In order that the sampler itself may not be a source of infection and cause the decomposition of the samples, it must be kept thoroughly clean and be frequently sterilized. Cleansing by means of a steam-jet is usually the most convenient and efficient method. All sampling devices should be thoroughly sterilized several times daily. The sample jars should be washed with hot water after each use and be thoroughly dried. The chemist should fully realize that in analyzing samples that are improperly drawn or cared for he is wasting his time and is obtaining misleading results.

Where measured samples are drawn at intervals by the workman, they may be conveniently stored in wide-mouthed, glass-stoppered jars. The stopper should have a small perforation in it to prevent sticking when the temperature of the factory falls. A convenient size for the jars is three liters and the mouth should be fully 13 cm. (5 inches) in diameter. The object of the large mouth is to obviate the use of a funnel and to prevent the workmen from spilling juice on the edges of the jar. Small metal-cups, with long handles, are convenient for measuring the samples. The size of the cups depends upon the number of tanks that are filled daily; usually a 3-5 cc. cup for the sucrose sample and 10-15 cc. for the density sample are suitable sizes. These cups should be thoroughly rinsed with juice each time before drawing the samples, and after the addition of samples the contents of the jars should be thoroughly mixed.

The sampling is complicated in a factory operating more than one tandem of mills, especially if these are operated at different capacities. If the mixed-juices are pumped through a single pipe-line, a pump sampler of the Calumet type may

be connected with the juice-pump and be operated by it. If the juices are pumped independently from each mill it may be necessary to attach a sampler to each mill-pump and composite the samples in proportion to the quantity of cane ground by each tandem. In some installations it is necessary to resort to hand sampling.

A preservative must be added to the samples in compositing. Samples for use in the Brix and ash determinations may be preserved during 24 hours by the addition of 0.3 to 0.5 cc. of a 40 per cent formaldehyde solution per liter of juice. These samples may also be preserved by the addition of mercuric chloride, using 1 part of the salt per 5000 parts of juice. Formaldehyde should not be used in compositing samples that are to be used in sucrose and glucose determinations.

The most satisfactory preservative of juices for sucrose and glucose tests is Horne's dry subacetate of lead. This is a very efficient preservative when used in the proportion of 12 grams per liter of juice. It will preserve a juice sample for periods far exceeding 24 hours. This salt must not be used in excessive quantities and after each addition of juice the sample should be thoroughly mixed with the preservative.

If the subacetate of lead is used in solution, an estimate of the probable volume of juice that will be included in the days' composite sample should be made and for each estimated 100 cc. 5 cc. of the lead solution should be accurately measured into the sample-jar. At the close of the day's work the volume of the sample and preservative should be ascertained and then sufficient water should be added to make the total dilution 10 per cent of the volume of the juice itself. This enables the use of Schmitz's table for sucrose.

It is preferable to composite the samples in the laboratory itself, thus giving the chemist a good control over the sample-boys, and making sure that the subsamples are drawn at regular intervals.

104. Sampling the Filter-press Cake.—The composition of the filter-press cake varies in different parts of the press and of the cake itself. This makes strictly accurate sampling impracticable since this work must be left in the hands of the pressmen. The best approximations and com-

parisons are obtained by cutting pieces of the cake systematically from various parts of the press.

The instrument shown in Fig. 53 is very suitable for this
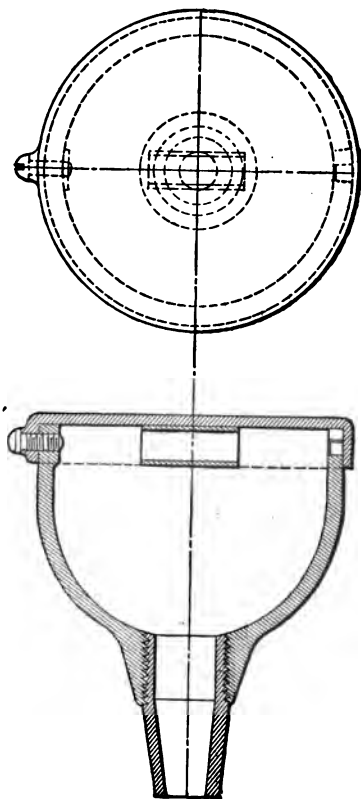
Fig. 53.

sampling. It is made of heavy brass and of such a size that it may readily be grasped by the hand over the cover. This latter is fastened to the body or receptacle by bayonet

catches and a set-screw. The cutter is a brass-tube $\frac{1}{16}$ inc'i thick and about $\frac{1}{2}$ inch in diameter at the cutting edge. The body of the tube is coned towards the receptacle, so that the plug of cake will readily pass into the latter. The cutting edge should be of the thickness of the tube to prevent damage to the filter cloth.

Several of these samplers should be provided so that one may be filled from each press. The pressmen should cut a number of plugs in the usual procedure, *e.g.* from various parts of the second cake, then from the fifth cake and so on. The plugs are accumulated in the receptacle, one remaining in the cutter and closing it. A small tube, open at both ends, is attached to the inside of the cover and holds a sponge saturated with formaldehyde, for the preservation of the sample. The sample should be sent to the laboratory each time a press is filled. This provides a check on the sampling and count of presses cleaned. The sampler should be thoroughly cleaned after removal of the plugs and returned to the presses.

The sample may also be obtained by means of a brass-tube, fitted with a piston for removing the plugs. A cork-borer may be employed for the purpose, but must be used with care on account of risk of cutting the filter cloth. The plugs should be stored in a covered vessel in an atmosphere saturated with formaldehyde.

It is difficult to control or check the sampling of the press-cake, especially as there is a natural tendency for the pressmen to sample only the hardest parts of the cakes. With the use of systematic methods of washing the cake the error of sampling, however, becomes less important as the loss of sugar is small.

The samples, collected as has been described, are not usually separately analyzed, but are composited, preferably during six-hour periods. Each time that a filled receptacle is received by the laboratory, the plugs of press-cake should be removed and chopped into fine pieces and be thoroughly mixed. A measured portion of the minced cake from each press should be placed in a jar in an atmosphere of formaldehyde. The united subsamples should be thoroughly mixed and analyzed once every six hours.

If preferred, the subsamples may be composited during a 24-hours period as follows: Weigh 25 grams of the 6-hours' sample and wash it into a glass mortar with water and 6 cc. of lead solution (149). Rub the cake to a paste to thoroughly incorporate the lead-salt with it. Cover the mortar pending the receipt of the next sample and proceed as before, adding the second portion to the first, with additional lead. The third and fourth subsamples are treated in the same way and finally the mixture is washed into a 400-cc. flask, diluted to the mark and polarized (149).

105. Sampling Sirups.—In cases where the sirup may not be thoroughly mixed in the tank before sampling, a "thief" sampler may be used. This consists of a tube, long enough to reach the bottom of the tank and provided with a suitable ball- or other type of valve. The tube is passed through the sirup, to the bottom of the tank, and on its removal takes with it a sample of each layer of sirup.

The method outlined on page 205 may also be used, but the above is somewhat more reliable.

In factories which pump all of the sirup through a single-pipe line to the storage-tanks, this material may be sampled by a Calumet pipe-line type of sampler (101) and with increased accuracy as compared with hand methods. This method is especially desirable when the sirup analysis is used as a basis for the calculation of available sugar.

106. Sampling Massecuite and Molasses.—The grain-massecuites are not usually of uniform density or composition. This lack of uniformity is caused by imperfect circulation in the vacuum-pan. This is especially noticeable in very dry massecuite boiled without the addition of molasses. The sample of massecuite should therefore be drawn, little by little, as the strike is being discharged from the pan. If it is not required to estimate the proportion of crystallized sugar in the massecuite, the sample may be drawn from the crystallizers, where this apparatus is used after allowing sufficient time to thoroughly mix the strike.

If the samples of the several strikes of massecuite included in the day's work are to be composited to form a single sample, a measured portion of each must be used. Sugar-

boilers usually fill the pans to the same point; in such cases, if the pans are of uniform size, one measure will answer for all, otherwise there should be a set of proportionate measures, one for each pan. A small stemless funnel of glass forms a convenient measure.

Molasses is sampled in the same way as sirup, and, according to the exigencies of the work, the samples are analyzed separately or are composited. A composite sample of the final molasses should be prepared from time to time for the determination of the sucrose by the Clerget method and the solids by drying for the calculation of the true purity. These samples should represent a definite quantity of the material.

107. Sampling Sugar.—The workman at the sugar-scale should remove a sample from each package of sugar as he
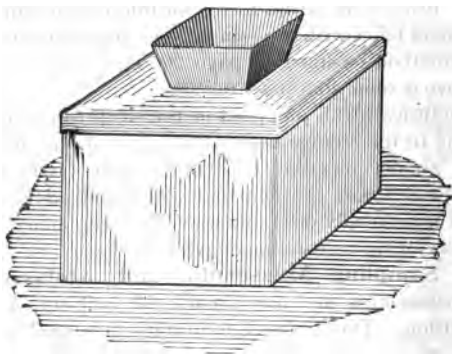
FIG. 54.

weighs it. The samples should be thrown into a tin-box provided with a funnel-shaped opening to receive them, as shown in Fig. 54. The composite samples so obtained should be analyzed at frequent intervals, preferably an analysis should be made every six hours, and the number of packages represented by the sample should be recorded for use in calculating the averages.

In sampling sugar in the packages a "trier" is usually employed (Fig. 55). The trier is a long trough-like instru-

ment, which, being plunged into a quantity of sugar, will, on withdrawal, remove a sample representative of the sugar through which it has passed. This sample should be thoroughly mixed, reducing all lumps, and exposing it to the air as short a time as possible.

The following are the U. S. Treasury instructions for sampling sugars:

"Sugar in hogsheads and other wooden packages shall be sampled by putting the long trier diagonally through the package from chime to chime, one trierful to constitute a sample, except in cases of small marks, when an equal number of trierfuls shall be taken from each package of the mark to

FIG. 55.

furnish the required amount of sugar necessary to carry out the provisions of the regulations. In the sampling of baskets, bags, ceroons, and mats the short trier will be used, care being exercised to take the sample fairly from the central contents of the packages, and in such manner that the samples from each class of packages shall be uniform in quantity. When the hard condition of the sugar renders the use of the short triers impracticable, the knife may be used."

The Treasury regulations require the sampling of all the packages in a lot, instead of a certain proportion of them, as formerly. This conforms to commercial usage.

108. Estimation of the Sucrose—Direct Method.— The first step in the analysis of the cane is the preparation of the sample. As has been shown a representative sample of the cane can be obtained in diffusion work, but with the milling process and without special apparatus it is almost impossible to accomplish this. With the usual facili-
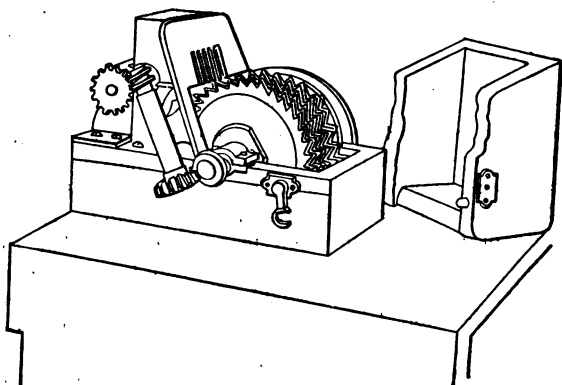
FIG. 56.

ties, such as a knife or shears, the sample of whole cane can neither be prepared rapidly enough to avoid error by evaporation, nor in a suitable state of division for a thorough extraction of the sucrose. In the analysis of whole canes it should be noted that the composition varies greatly in different parts of the stalks, thus complicating the preparation of the sample.

Whole cane can be rapidly and properly shredded by

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means of Hyatt's cane-reducer,[1] Fig. 56. The essential
parts of this machine are a cylinder, carrying a number
of staggered or "drunken" saws; the saw-disks are parallel
to one another and between them, bearing lightly on the
cylinder, are steel vibrators or fingers. A forced feed is
arranged to press the canes against the saws. In operating
the machine, the saws are driven at a very high speed, and
on account of the staggering of the blades every part of
the cane is reduced to a fine saw-dust and hair-like fibers.
The machine throws the prepared cane into a box where it
is protected from moisture.

With a large Hyatt machine the author has readily
obtained an almost complete exhaustion of the cane in
diffusion work on a manufacturing scale, with very little
dilution of the juice. In many tests, the sucrose remaining
in the residue from the diffusion was never more than 0.07
per cent of the weight of the cane.

For the direct estimation of the sucrose in the whole cane
proceed as follows: Place 100 grams of prepared cane in a
suitable dish or beaker and add approximately 200 cc. of
boiling water and boil during ten minutes; carefully drain
off the liquid and add another portion of 200 cc. of water,
and again digest during ten minutes. Repeat these diges-
tions with water in all seven times, and after the last press
the residue in a hydraulic or other powerful press, uniting
the portions of solution drained from the chips. Cool the
liquid and weigh it and also determine its degree Brix.
To 100 cc. of this solution in a sugar-flask add subacetate of
lead for clarification and complete the volume to 110 cc.
After thorough mixing and filtration polarize the filtrate,
using a 600-mm. observation-tube. Divide the polariscope
reading by 3, since a triple-length tube is used, and calculate
the per cent sucrose in the solution by Schmitz's table,
page 506. From the per cent sucrose in the solution and the
weight of the latter, calculate the weight of sucrose. This
number is the weight of sucrose in 100 grams of cane or the
percentage of sucrose in the cane.

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[1] This machine has recently been somewhat modified from that of
the figure and it is now known as the "Warmoth-Hyatt cane reducer."

109. Estimation of the Sucrose. Indirect Methods.—In the earlier days of laboratory control of cane-sugar factories, the sucrose was estimated by applying the percentage of sucrose in the normal juice to its weight as derived by deducting the marc (fiber) from 100. O. H. Francis [1] called attention to the error of this method in assuming the juice of the cane to be homogeneous. Many other experimenters have also shown that the composition of the juice varies in the same part of the stalk and that the cane contains water, termed colloidal water by Scheibler, that is almost or quite free of sugar. If a piece of a stalk of cane be entered into a small hand-mill and be slowly pressed, water will drip from the free end. In view of these considerations it is evident that an indirect estimation of the sucrose content of the cane must include the use of a factor to reduce to terms of the undiluted juice. This factor is necessarily quite variable and no great reliance should be placed upon analyses in which it is used.

The above method is discussed here on account of its use by many chemists and its bearing upon methods of stating the efficiency of mill-work.

As in the beet-sugar industry, it is the custom of many chemists to deduce a factor from experimental data, corresponding to the percentage of normal juice in the cane, and apply this number in calculating the sucrose by the indirect method. In order that such a factor may be applicable, the experimental data must be obtained under the same milling conditions as in the extraction of the juice sample upon which to base the calculations. Such a factor can only be properly calculated from data obtained by actual experiment with the factory mills and even when so deduced is but an approximation, since the composition of the cane is constantly changing.

The following is the customary and probably the best method of indirect analysis of the cane in working with or without saturation. The weight of the cane is taken as reported by the cane department; the weight of mixed or

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[1] The Royal Agricultural and Commercial Society of British Guiana, 11th June, 1885.

diluted juices from all the mills is ascertained by direct weighing or by measurement and calculation by the laboratory; the weight of bagasse is estimated by deducting the weight of the diluted juice from the sum of the weights of the cane and the saturation-water; the sucrose is determined in the juice and the bagasse by direct analysis. Manifestly the weight of sucrose in the cane is the sum of the weights of sucrose in the juice and bagasse, and this number divided by the weight of the cane and multiplied by 100 gives the percentage of sucrose in the cane.

There are several conditions that may lead to inaccuracy in the above method. The juice may be diluted by leakage of the water used in cooling the mill-journals; the bagasse parts with more or less moisture by evaporation in passing through the mills; there may be inaccuracies of weights, measures and analyses. The first of these need not be expected where modern mills of good construction are operated. With the old types of mills, however, it is often necessary to run cooling water upon the bearings and a part of this is very liable to leak into the juice. Such leakage may usually be detected by noting the relation between the percentage of saturation-water and the dilution number. The error from the evaporation of the moisture cannot be eliminated, but is probably usually very constant in a given milling-plant. Inaccuracies of weights, sampling and analysis are usually avoidable. Inaccuracy in the measurement or weight of the saturation-water, which is used in calculating the weight of the bagasse, should be avoidable, but is a frequent source of error.

The impossibility of accurately sampling whole canes usually precludes the use of the direct method of analysis in factory control, hence the method just described should be given preference.

110. Determination of the Woody Fiber or Marc.—
The samples should be very finely shredded. Transfer 50 grams of the material to a tared beaker of 400 cc. capacity. Stretch a piece of washed linen over the top of the beaker, fastening it in place by a strong rubber band. An opening should be left in the linen, opposite the lip of the beaker for replenishing the water. The linen is designed to serve

as a filter. Digest the cane-shreds two times of ten minutes each with warm distilled water, not hotter than 75° C., pouring off the solution each time through the linen, and washing back into the beaker the fragments of cane that adhere to the filter. After the digestions with warm water, digest the cane-shreds five times, of ten minutes each, in boiling water, pouring off the liquid as before. Dry the beaker and residue in an oven at 100° C., until there is no further loss of weight, or until there is a slight gain over the previous weight. Use the smaller weight in the calculation. The weight of the residue multiplied by 2 is the percentage of fiber or marc in the cane.

The dried fiber and linen attract moisture with extreme rapidity; therefore the beaker and contents should be cooled in a desiccator and then weighed as quickly as possible. Preparatory to weighing the beaker and residue, their approximate weight should be placed on one of the balance-pans.

Special apparatus should be employed where frequent direct fiber-determinations are required. This should be capable of operating with comparatively large quantities of cane or bagasse in order to reduce the sampling error. A convenient apparatus is shown in Fig. 57. This is a simple form of Soxhlet's extractor and is made of thin copper or brass. The body of the extractor, A, is approximately 3.5 inches in diameter and 12 inches long. Lugs are provided to support a cylinder, B, about 3 inches above the bottom of the extractor. The cylinder has a removable cover of 80-mesh wire-gauze and the bottom is of the same material. A cylinder of this size will hold from 50 to 100 grams of shredded bagasse or a larger weight of cane. The chamber below the lugs is to provide drainage space. A weighed quantity of shredded cane or bagasse in the cylinder B is
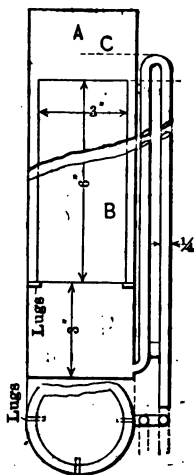
Fig. 57.

placed in the extractor and a slow stream of cold water is run upon it. The water is quickly removed by the syphon-tube when it reaches the level C. The rate of syphoning may be controlled by partly closing the outlet with a plug of wood. The lower chamber should be large enough and the rate of syphoning slow enough to permit partial drainage of the cylinder before the water again rises to the level of the cane. Hot water should be substituted for the cold after a few extractions. If desired the extractor may be heated with a lamp, but in this event the lower chamber should be deepened and the outlet should be an inch or more above the bottom.

After thorough extraction, close the water-inlet and drain the fiber. Remove the cylinder from the extractor and place it in an oven to dry the fiber, or more properly speaking, the "marc." Drying may be promoted by soaking the marc in strong alcohol. A cylinder of the water-saturated marc may be dried in about four hours in the special bagasse-oven, Fig. 81. The cylinders and extractors should be made with a view to the use of an oven of this type, and therefore much larger than has been indicated.

According to Pellet,[1] the use of alcohol instead of water in marc determinations is objectionable. The alcohol precipitates silica, phosphates, and nitrogenous and non-nitrogenous matters, which are held by the fiber and exaggerate its quantity. See 153.

There are several processes of direct-fiber determination, using special apparatus, that are accurate as analytical methods for the particular sample, but they use such small portions per test that the sampling error becomes quite large, and the results valueless.

The following indirect methods of fiber determination are those recommended and usually employed in mill control: (1) The bagasse is sampled and the fiber is directly determined in it. The bagasse produced per cent cane×the per cent of fiber in the bagasse×100 = per cent fiber in the cane. (2) The per cent sucrose in the bagasse and the purity of the residual juice and the moisture are determined. The

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[1] Bulletin Assoc. des Chimistes, 22 April, 1905.

percentage of juice solids in the bagasse is calculated from the percentage of sucrose and the purity of the residual juice. The sum of the juice solids and the moisture deducted from 100 give the percentage of fiber in the bagasse. The purity of the juice flowing from the bagasse-roll of the last mill in the train is considered to be that of the residual juice.

The following example illustrates the second indirect method: Per cent of bagasse, 25; sucrose in the bagasse, 4 per cent; moisture, 48 per cent; residual juice purity, 78 per cent; then $4 \div .78 = 5.13$ per cent juice-solids; $100 - (5.13 + 48) = 46.87$ per cent, fiber in the bagasse; $25 \times .4687 = 11.72$ per cent, fiber or marc in the cane.

The writer has compared a large number of analyses by method (1) with the calculated fiber by method (2). The agreement by the two methods is so good that he has discontinued the direct determinations of fiber in the bagasse in the factories under his supervision. (*See also* **153.**)

ANALYSIS OF THE JUICE.

111. Determination of the Density.—The density of the juice is usually determined by means of an hydrometer (**94**), though a pyknometer (**96**) or the Westphal balance (**95**) may be used. The Brix spindle is the more convenient hydrometer for this purpose, since its readings are used in calculating the coefficient of purity.

The readings on the Baumé scale, or the specific gravity as determined by the Westphal balance or pyknometer, may be converted into degrees on the Brix scale by means of the table on page 477 or page 482, according to the standard temperature selected.

In using the hydrometer, fill a wide cylinder to the brim with the sample of juice and set it aside for the escape of air-bubbles. The time required for this varies from a few minutes to half an hour, but usually ten minutes suffice. The spindle should be lowered into the cylinder, after the escape of the bubbles, causing the juice to overflow and carry away with it the froth and mechanical impurities floating upon the surface. It is well to blow on the surface of the juice as it overflows to help remove the froth. The spindle should now be lowered farther into the juice, until it floats, taking care not to wet the stem above the point to which it sinks. After allowing sufficient time for the temperature of the spindle to reach that of the juice, read the scale as directed in **94** and illustrated in Fig. 47. The temperature of the juice should be noted for use in correcting the observed density.

The temperature correction when using spindles whose normal is $17\frac{1}{2}°$ C. is made with the aid of the table, page 489. For example: Let $18.15°$ Brix at $24°$ C. be the observed density and temperature. Referring to the table of correc-

tions, under the heading "Approximate degree Brix and
Correction," follow down the column 20, the degree Brix
nearest 18°, to opposite the temperature 24° C., and take
off the correction .44, which must be added to 18.15, mak-
ing the corrected degree Brix, 18.59. Had the tempera-
ture been below 17½° C., the correction would have been
subtractive. Similarly, the table on page 490 is used in
making temperature corrections for instruments standard
at 20°/4° C. The table of comparisons for these instruments
is given in page 477.

**112. Determination of the True Degree Brix or
Total Solids by Drying.** *Carr and Sanborn's Method.*[1]—
Prepare pumice-stone in two sizes. One size should pass a
1-mm. sieve and the other should pass a 6-mm. sieve, cir-
cular perforations. Place a layer of the finer pumice-stone
3 mm. thick on the bottom of a small metal dish; lead caps
for bottles are convenient and inexpensive for this purpose.
Place a layer of the coarse pumice-stone 6 to 10 mm. thick
upon the first layer. Add such a quantity of the juice to
the tared dish and pumice-stone as will yield approximately
1 gram of dry matter. In weighing the solution use a
weighing-bottle. Dry to constant weight in a water-
oven, making trial weighings at intervals of two hours.
The drying may be conducted in a vacuum-oven at about
70° C. in case of materials containing much readily oxidizable
matter.

The weight of dry matter divided by the weight of juice
used and the quotient multiplied by 100 =per cent of total
solids.

Method using vacuum-apparatus.—This method was sug-
gested to the author by that of Courtonne, from which it
differs in the construction of the oven and drying-bottles.
Courtonne heats the bottles in water, and makes no pro-
vision to prevent the return and re-evaporation of a part of
the water of condensation.

The oven is shown in section, in Fig. 58, and the bottles
and trap in perspective. The walls of the oven are double
and are filled with plaster of Paris, C; the bottom is also

[1] Bull. 46 Div. Chemistry, U. S. Dept. Agriculture, p. 45.

double, and the space is filled with air. A fan, *D*, driven by a toy steam-engine or other small motor, agitates the air inside the oven and insures a very uniform temperature in all parts of it.

The drying-bottles, *A*, are connected by means of short tubes with a central vacuum-pipe, *E*, which is in turn connected with an ordinary filter-pump or other vacuum-pump. Each bottle may be removed by closing a cock *G* without disturbing the others. A small glass trap, *H*, shown at the right of the oven, in detail, prevents any moisture, from
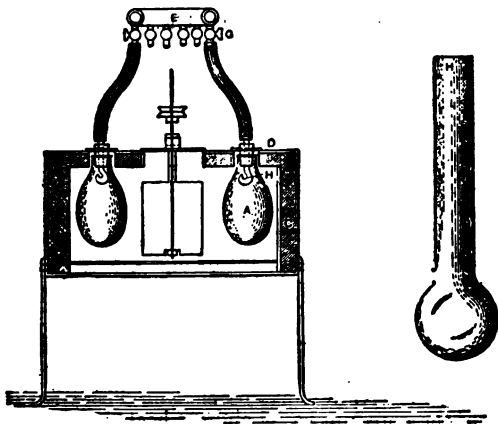
FIG. 58.

condensation in the tubes, from falling back into the bottle.

The following procedure is advised: Dry a small quantity of pieces of pumice-stone in one of the bottles; tare the bottle and then distribute a weighed quantity of about 5 grams of juice over the stone. All weighings should be made with the glass stopper in the bottle. Insert a rubber stopper, provided with a glass trap, *H*, in the neck of the bottle and connect it with the vacuum-pipe, *E*, by means of a rubber tube. Heat the oven to 100° C., keeping the fan in motion. A vacuum of 20 inches is usually sufficient. The calculations are made as in the preceding method.

Materials containing levulose should be dried at moderate temperatures, preferably in a vacuum-apparatus. The risk of decomposition of the levulose is lessened if nearly all the water be driven off at a low temperature before heating to expel the last of it.

A Convenient Vacuum-oven.—A convenient apparatus for drying materials in vacuo is the distilling device shown in Fig. 59. This consists of a glass dome fitted to a porcelain vessel, the joint being made with a rubber gasket. The porcelain vessel is fitted into a special water- or steam-bath. Connection is made with the factory's vacuum-system by means of pressure-tubing. The dishes rest upon the
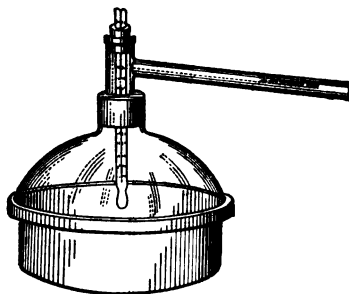
FIG. 59.

bottom of the porcelain vessel and are heated to the temperature of the bath. A dish should not be placed directly under the outlet except this be provided with a water-trap similar to that in Fig. 58.

Pellet's Method for Total Solids.—Pellet uses a shallow nickel capsule 85 mm. in diameter and 20 mm. deep at the center. The dish has a central depression about one-third the total depth of the dish and one-third its diameter. Freshly ignited pumice-stone, ground to pass a 1-mm. sieve, is distributed around the border of the capsule, leaving the central depression free. The capsule, including the pumice-stone and a small glass rod, is warmed, then cooled in a desiccator and tared. The material to be tested is placed in the depression and the dish is reweighed. In the case of juice,

10 grams may be used. This is then diluted with a little distilled water and by tilting the capsule it is absorbed by the pumice-stone. The stone is now distributed evenly over the entire bottom of the capsule. In testing massecuite, etc., the material (about 3 grams) is weighed in the central depression and is then dissolved in about 5 cc. of hot distilled water. This solution is absorbed by the stone and is followed successively in the same manner with two additional small portions of water. The rod is used to promote solution. Finally the stone is distributed as before and the material is dried in the oven. A drop or two of ammonia should be added to material containing even a trace of acidity.

In another method, Pellet makes a parallel test, using pure sugar to which water equivalent to that in the material to be tested has been added. The capsule containing the sugar is weighed at intervals and when it ceases to lose moisture the other dish is assumed to contain only dry matter.

Josse's Method.—This method was originally used in certain agricultural work. It has been slightly modified from time to time. The modification of Tempany and Weil [1] is given here.

A strip of S. & S. filter-paper, No. 597, 58 cm.×2 cm., is rolled into a tight coil and is placed in a weighing-tube 12 cm. × 2 cm. After thoroughly drying the paper, the tube is stoppered and weighed. The stopper is now removed and 10 cc. of juice is distributed over paper. The tube with the stopper removed is now placed in a drying-chamber contained in a steam-jacket. The chamber is heated with steam, while a current of air, dried by passing it through sulphuric acid, followed by travel through calcium chloride, is drawn through it by an aspirator. The moist air leaving the chamber may be passed through drying-bulbs and the water be collected and weighed as a check. Stop-cocks are arranged to control the air-current and a mercury-column to regulate the vacuum.

113. Estimation of the Total Solids from the Refractive Index.—Tolman and Smith's [2] investigations

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[1] W. I. Bul. 1912, 12, 89.
[2] J. Am. Chem. Soc., 1906, 28, 1476.

showed that most sugars in solutions of equal percentage composition have the same refractive indices, also that Gerlach's table of Brix hydrometer corrections may be used with small error to correct from room temperatures. Main [1] was the first to use the refractometer in refinery work. He found that the refractive index indicates accurately the content of solid matter in all but low products. Geerligs and van West [2] were the first to use the refractometer in cane-sugar factories. The tables of Tolman and Smith, Main, and Geerligs, after temperature correction agree closely with one another. The refractometer is affected only by the solids in solution, therefore if the material under examination contains insoluble matter this is not included in the estimate of the solids. Within its limitations, i.e., in materials containing only soluble solids and a small proportion of non-sugars, the refractometer is capable of giving very accurate indications as to the solids contents, usually quite as accurate as those by drying. The refractometric results with materials of low purity are usually intermediate between those by hydrometer and actual drying. The cane-sugar maker, in order to adopt the refractometer in massecuite and molasses analysis, must completely change his idea of the suitable purities or at least for a time. These considerations and the conditions obtaining in Cuba have deterred the author from applying the refractometer in the factories under his general superintendence of manufacture.

Three instruments, by Carl Zeiss of Jena, are used in the refractometric estimation of the solids in sugar materials, viz.: (1) Abbe refractometer; (2) immersion refractometer; (3) sugar refractometer, a special form of Abbe instrument.

(1) *The Abbe Refractometer*, Fig. 60, consists essentially of two flint-glass prisms A and B of index $N_D = 1.75$, cemented into a metal mounting, and a compensator. The mounting of one of the prisms is hinged at C so that it may be separated from the other. A drop or two of the liquid to be tested is placed upon the polished surface of the fixed prism, A, and the hinged prism is carefully closed against it

[1] Int. Sugar Journ., 1907, 9, 481.

[2] Archief, 1907, 15, 487. Abs. in Chem. Centralbl., 1908, 79 (1), 800.

and the instrument is revolved to a convenient position with respect to the light. The light, preferably from an electric lamp, is reflected upon the lower prism, B, by the mirror, R. The prisms are attached to a movable arm, J, which carries a reading-glass, L, and the telescope to the scale, S. To set the instrument, the movable arm, J, is adjusted until the intersection of the reticule of the telescope cuts the line separating the dark from the light portion of the field. The refractive index is then read off the scale with the reading-glass. Uniform temperature conditions should be maintained by means of a flow of water from a large vessel through the tubes D, E, in the direction of the arrows. The temperature of the observation should be noted and the correction be applied, using the table accompanying that of
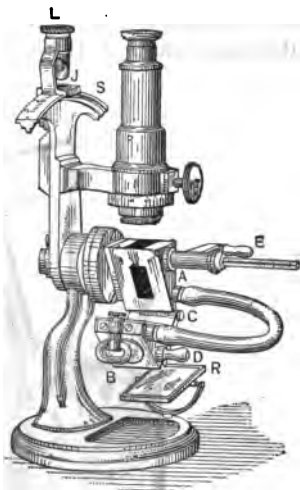
FIG. 60.

Geerligs, page 494. The percentage of dry matter corresponding to the index is given in Geerligs' table. The compensator, consisting of two small prisms placed in the telescopic tube, serves to eliminate the dispersion produced by the prisms. By rotating the small prisms with respect to each other the color is removed from the field. This compensation is necessary before making the observation. The prisms should be cleaned after use with filter-paper dipped in warm water and then be dried with soft linen. The instrument may be tested with air-free distilled water (index = 1.33298) or with standard plates.

(2) *The immersion refractometer*, Fig. 61, is adapted to solutions containing up to 21.7 per cent of sugar and is not so well suited to general sugar-house work as the instruments (1) and (3) and therefore will not be described. Within its

range it is more accurate than the other types and is quite
suitable for juices of the usual range of density.   Instruc-
tions and special tables are supplied by the dealers with the
immersion instrument.

(3) *The sugar refractometer*,[1] Fig. 62, is a special form of
Abbe's instrument and has been designed especially for use
in the sugar-industry.   It has the double prisms of the Abbe

<p align="center">Fig. 61.</p>

instrument and differs from this in the optical nature of the
glass forming the prisms, designed by Schönrock, and in
having a modified comparator.   The graduation is upon a
cylindrical glass strip located in the field of view.

The divisions of the scale read percentages of dry substance,
the interval between 0 to 50 in 1 per cent and 50 to 85 in

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[1] Abstracted from Zeiss' instructions.

0.5 per cent. Within the range from 0 to 60 the scale is graduated according to Schönrock's table and from 60 to 85 according to Main's table. The temperature standard, 20° or 28° C., is engraved upon the instrument.

The refractometer is shown in about one-third size in Fig. 62. The upright *E* is fitted with a hinge *J* which carries the casing *G*, together with an independently hinged telescope.
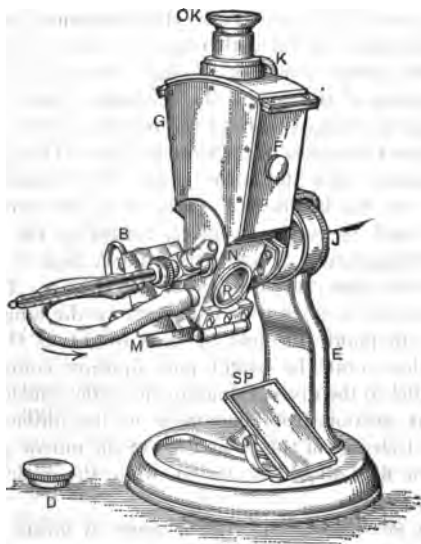
FIG. 62.

The eyepiece *OK* and the handle *K* of the telescope are shown. The prisms, *M*, *N*, are provided with an arrangement for temperature control similar to that of the Abbe instrument, (1). The prism is fitted with a window at *R* which is usually covered with the cap *D*. This window is used when observing very dark-colored solutions. The cap *F* gives access for adjusting the zero of the scale.

Setting the Refractometer.—Place the instrument in front of the observer with the handle *B* on the left and the mirror *Sp*

toward a window or an incandescent electric or gas lamp.. The source of light should be about 18 inches from the mirror.

Applying the Sample.—Open the prisms by means of the handle *B* and place a drop of the solution upon the matted surface of the lower prism with a rod. A smoothly rounded glass rod should be used. Close the prisms immediately after applying the solution.

Regulation of the Light.—Place the instrument so that the sides *G* are symmetrical with respect to the source of light. Adjust the mirror to reflect the light through the frame of the mounting of the prism *M*. Complete this adjustment by moving the hinged body of the refractometer as a whole.

Setting the Instrument to the Critical Line.—The eyepiece *Ok* can be turned over the entire range of the scale with the assistance of the handle *K*. First set to the zero point of the scale and focus the eyepiece, arranging the mirror to throw a strong light. Then by rotating *K* pass to the higher parts of the scale, following with the mirror. If need be turn the entire body of the instrument on the hinge, *J*. Up to a certain point the field appears bright at the middle; beyond this point the bright part appears bounded by a line, parallel to the division lines of the scale, which separates the bright portion from one more or less intensely dark. By a slight change of the inclination of the mirror the brightness of the field should be tested, while the critical line remains stationary.

Reading the Scale.—Turn the eyepiece by means of *K* until the critical line coincides with the point of intersection of the cross-hairs. Read the scale at the point where the critical line crosses it. Fractions of a per cent must be estimated.

In observing very dark solutions, turn the mirror over and remove the cap *D* from *R*. The field will appear uniformly white to an unpracticed eye and the critical line may even not be seen. Rock the telescope and a fine limiting line will be noted between a very dark and a very bright part of the field. Bring this line into coincidence as has been described and read the scale. Temperature-correction tables are supplied by the maker with each instrument.

Examining Viscous Solutions.—Slightly warm the prisms by

circulating water through the mounting. Apply the solution to the prism and promptly make the observation.

114. Notes on the Estimation of Total Solids.—The determination of the total solids and moisture in sugar-house materials is one of the most unsatisfactory tests the chemist is called upon to make. This is due to the ready decomposition of several of the constituents and under some conditions to their tendency to occlude moisture. It is advisable to select methods that give fairly comparable results under average conditions and to use these at all times. If the drying is conducted in an air-oven, the same weight of material, the same size and kind of a dish, and the same temperature and heating-period should be adhered to at all times for a given class of materials. A temperature that is suitable, e.g., to a high purity large crystal sugar is too high for a soft sugar of low polarization. The first requires a comparatively high temperature (105° C.) to drive off the occluded water and the other a very low temperature to avoid decomposing the invert sugar.

115. Determination of the Sucrose. Special Pipette for Measurements.[1]—This method is applicable with juices that have not been preserved with subacetate of lead. The pipette, Fig. 63, is so graduated that if filled to the mark, corresponding with the observed (uncorrected) degree Brix, with juice, it will deliver 52.096 grams, i.e., two normal weights of the liquid. Evidently the pipette may be graduated for other quantities than two normal weights (52.096 grams), but it is usually carried in stock in the 2-normal weight size, by the dealers, and graduated for a range of densities of 5° to 25° Brix.

[1] This pipette was devised by C. A. Crampton and G. L. Spencer, independently and at about the same time. It is termed "Crampton's" or "Spencer's sucrose pipette" by the dealers.

Fig. 63

Pipettes must be graduated to order for the new normal weight, 26 grams, which is used with the true 100 cc. flask. These instruments, called sucrose-pipettes, are usually made with a long delivery-tube, but the author prefers a tube about four inches long. With the short tube the pipette may be supported by the flask while draining, leaving the chemist free to continue a series of such measurements with other pipettes.

In using this pipette in the analysis of a juice, proceed as follows: Determine the density of the juice with a Brix hydrometer, noting the degree Brix without temperature correction. Fill the pipette with juice to the mark corresponding with its observed degree Brix, and discharge it into a 100-cc. flask. Add 3 to 5 cc. of diluted lead subacetate solution (290), complete the volume to 100 cc. with water, mix thoroughly and filter the contents of the flask. Polarize the filtrate, using a 200-mm. tube, and divide the polariscope reading by 2 to obtain the percentage of sucrose. The juice should not be expelled from the pipette by blowing, and sufficient time should be allowed for thorough drainage.

The sucrose pipette may be used in connection with Horne's dry-lead method by making the measurement after filtration, at the temperature of the Brix observation. This use of the pipette obviates that of Schmitz's tables, but involves completion of the volume to 100 cc.

The calibration of pipettes should be verified against a balance. A volume of sugar solution corresponding to an uncorrected degree Brix should be measured in the pipette. If the instrument is correctly graduated it should deliver 52.096 grams of the solution.

It is not advisable to use these pipettes with liquids of a higher density than 25° Brix or of greater viscosity than cane-juice. These pipettes are usually used in the analysis of miscellaneous samples of juice and in the rapid testing of diluted massecuites and molasses for guidance in the vacuum-pan work. They should be frequently cleaned with a strong solution of chromic acid in sulphuric acid.

116. Determination of the Sucrose. General Methods.—The necessity of adding subacetate of lead to the

juice in sampling somewhat complicates the measurement
of the sample for analysis.

If formaldehyde or mercuric chloride is used, which the
author does not recommend, the sample for analysis may be
measured with the sucrose pipette or otherwise.

With the solution of subacetate of lead used as a pre-
serving agent proceed as follows:

Determine the degree Brix of the duplicate sample.
Measure the composite sample, including the lead solution;
subtract the volume of the lead solution from the total
volume and from these data calculate the amount of water
required to dilute the juice to 110 per cent of its original
volume. Add the calculated volume of water, and mix the
juice, lead salt, and water thoroughly, filter and polarize the
filtrate, using a 200-mm. tube. The calculation of the per-
centage of sucrose is made with the aid of Schmitz table,
page 506.

Example showing the methods of calculation:

    Volume of juice and lead solution. .... 2705 cc.
    Volume of lead solution used. . ... 125 "
                                               ————
        Volume of juice. .... 2580 cc.
    Ten per cent of the volume of the juice =
        one-tenth of 2580. . ... 258 cc.
    Volume of lead solution used. . ... 125 "
                                               ————
        Volume of water required to be added.. 133 cc.

The total volume, *i.e.*, 2705 + 133 = 2838 cc. or 110 per
cent of the volume of the juice (2580 cc.).

Degree Brix of duplicate sample (uncorrected)........18.0
Polariscope reading. 60.5

It is advisable to acidulate the water used with acetic
acid to restore the normal rotatory power to the levulose
that may be present.

The sucrose is ascertained from Schmitz table as follows:
Referring to the table (page 506), under the column 18, the
nearest degree Brix to that observed, opposite 60, the whole
number of the polariscope reading, is 15.98; add to this
number 0.13, which is found in the small table opposite 0.5,

the tenths of the polariscope reading. The completed
number, 16.11, is the per cent of sucrose in the juice.

The sucrose may be determined in a juice, not stored with
lead subacetate, as follows: Measure 100 cc. of juice in a
sugar-flask, i.e., a flask graduated to hold 100 cc. and 110 cc.,
add sufficient subacetate of lead solution for the clarification,
usually 6–8 cc.; complete the volume to 110 cc., previously
acidulating the solution with acetic acid, mix, filter, and
polarize the filtrate as usual. The percentage of sucrose in
the juice is calculated by Schmitz table, as described above.

In all juice analyses by these methods, requiring especial
accuracy, a correction should be made for the error due to
the volume of the lead precipitate (see **83**) and the solutions
should be acidulated with acetic acid.

The analysis of the juice may be made by W. D. Horne's
method [1] using finely powdered dry subacetate of lead for
the clarification. This method as described by Horne,
requires no measurements when applied in the analysis of
juice. The dry subacetate of lead is added in sufficient
quantity to a portion of the juice for clarification, and after
thorough mixing and filtration the filtrate is polarized as
usual. Approximately 1–3 grams of dry subacetate of lead
are required for the clarification of 100 cc. of juice. The
calculation of the percentage of sucrose is by Schmitz's table,
page 500. Schmitz's original table, page 506, may be used
if the polariscope reading be divided by 1.1.

This method eliminates the error due to the volume of
the lead precipitate in other processes of analysis, but it
must be used with caution for juices or products containing
invert-sugar, owing to its reaction with levulose. (*See* **84**.)
Fully mature tropical cane contains but small traces of
levulose and often none at all, whereas unripe or damaged
canes may contain much.

Horne's dry-lead method is of great convenience in factory
control. It may be used in the storage of juices in composit-
ing samples and does not dilute them. The juice usually
contains so little levulose that the influence of the lead upon
it may be neglected. If necessary the levulose error may be
eliminated by the following procedure, but with the introduc-

[1] Journ. Am. Chem. Soc., **26**, 186; Int. Sugar Journal, **6**, 51.

tion of a precipitate-volume error: Shake the sample thoroughly and while the precipitate is still in suspension measure 100 cc. of the mixture in a sugar-flask and dilute it to the 110-cc. mark with dilute acetic acid of sufficient strength to slightly acidulate the contents of the flask. Filter, polarize and calculate the percentage of sucrose by the Schmitz's ta'.le, page 506.

According to Cross,[1] dry oxalic acid may be used instead of acetic acid and thus eliminate both the levulose and the precipitate-volume errors: After the addition of the dry-lead salt, with thorough mixing, add dry-powdered oxalic acid in sufficient quantity to precipitate almost all of the lead in solution and filter. Polarize the filtrate and calculate the percentage of sucrose by Schmitz's table, page 500.

Neutral acetate of lead may be used in the analysis of juices and many other materials, but not as a preservative. Dr. Horne's method suggested to the writer that dry normal acetate of lead might be used in analysis to eliminate both the levulose and precipitate volume errors. According to the manufacturers, the dry normal acetate may contain some basic acetate. A number of experiments were made along the lines of Dr. Horne's method, using the dried acetate, and with good results. An excess of the salt over the requirements for clarification should be avoided.

117. Determination of the Sucrose by Clerget's Method.—Clarify the juice sample by one of the methods of the preceding paragraph. Remove the lead by precipitation with oxalate of potassium or dry sodium oxalate. Invert the sucrose and proceed as is described in **134.** It is usually convenient in factory control to use a composite sample of the juice preserved with Horne's dry lead and representing a day's work. If proper precautions are observed, the sampling period may even be longer than a day.

118. Determination of Glucose[2] (Reducing

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[1] La. Bulletin No. 135, Agric. Expt. Sta., Wm. E. Cross, 39.

[2] As is customary in the cane-sugar industry, this word is used throughout this book to include the dextrose and levulose in the material. The reducing-substances of cane and its products are various proportions of dextrose and levulose and possibly very small quantities of other reducing-substances. The mixed reducing-sugars are often termed "invert-sugars."

Sugars). Gravimetric Methods.—The method to be used in glucose tests depends upon the composition of the material, especially as regards the relative proportions of sucrose and glucose. Three methods will be given. The first and third are of general application and the second should only be used when the juice contains but a very few tenths of a per cent of glucose, which is not often the case.

(1) *Method Using Meissl and Hiller's Factors. Preparation of the Solution.*—This method is recommended by the author for all sugar-cane products. Prepare a solution of the juice as for polarization except as to the quantity of the material and that the *neutral acetate of lead* should be used. Before completing the volume to the mark on the flask, add sufficient oxalate of potassium to precipitate the excess of lead. Complete the volume, add a small quantity of dry kieselguhr (diatomaceous earth) and thoroughly mix the contents of the flask. The filtration should not be immediate, since about five minutes' standing is necessary to insure full action of the oxalate. After sufficient time, filter the solution. Should the filtrate not be perfectly clear, add more kieselguhr and refilter.

The solution may also be prepared without dilution as follows: Add the minimum quantity of Horne's dry subacetate of lead to the sample of juice that will suffice for clarification; follow the lead with sufficient dry sodium oxalate, in small portions with frequent shaking, to precipitate the lead; add kieselguhr to promote filtration and mix thoroughly and filter. All traces of lead must be removed.

The selection of a reagent for deleading solutions for glucose tests is of very great importance. A large number of comparative tests were made by the direction of the author in the selection of methods for use in the laboratories of the factories and refineries under his control and with the result that present information shows that the oxalates of potassium and sodium and dry oxalic acid are more suitable deleading agents than the carbonate or sulphate of sodium. Special care to avoid inversion must be used with oxalic acid. Sufficient time must be allowed for the precipitation of all the lead and thorough filtration should follow.

The next step in the analysis is the estimation of a suitable quantity of the material for the test. This need be determined but once in the manufacturing season, and afterwards the quantity may be readily varied as the maturity of the cane advances. Prepare a series of large test-tubes by adding 1, 2, 3, 4 and 5 cc. of the solution prepared as described above successively. Add 5 cc. of mixed Soxhlet's solution (**297**) to the contents of each tube and heat to boiling during about two minutes. Allow the precipitâtes to settle. Compare the color of the supernatant liquid in each tube and note that which has the lightest tint, but is distinctly blue. Measure 20 times the volume of the deleaded solution that this tube contained into a 100-cc. flask and dilute it to the mark with water. For example: Tube No. 3 is selected; $3 \times 20 = 60$ cc. of the original solution, or if the second method of preparation is used, 60 cc. of juice in 100 cc. The volume of juice measured must be mult'plied by its specific gravity to ascertain its weight. It is convenient to use Spencer's glucose-pipettes, on the principle of the sucrose-pipette, in making these measurements (**115**). These pipettes should be provided in a series of four, advancing by 20 grams. The calibration of the pipettes should always be checked against a solution of known degree Brix.

The Reduction to Cuprous Oxide.—Measure 50 cc. of Soxhlet's solution (**297**) *i.e.*, 25 cc. of the copper solution and 25 cc. of the alkali solution, into a 400-cc. beaker and add 50 cc. of the sugar solution. Heat the contents of the beaker to the boiling-point, taking four minutes to reach this temperature and continue the heating with very slight ebbulition during two minutes. At the conclusion of the heating-period add 100 cc. of *cold recently boiled* distilled water and immediately filter and collect the cuprous oxide, using one of the methods described farther on in connection with the various processes of ascertaining the weight of copper.

All the details of the method of preparing the solution and conducting the reduction must be strictly adhered to that the results may be comparable and approach the absolute glucose content. The beakers should be of Jena or similar glass, and all be of one size, preferably not larger than 400 cc., and of uniform thickness and diameter. The

boiling should not be violent but only just apparent. The addition of cold water and the filtration should be prompt.

The Filtration and Reduction or Calculation to Metallic Copper.—The invention of the alundum filtering crucible and Spencer's method of making the joint at the rim of the crucible instead of the bottom as with the Gooch crucible, have greatly simplified this stage of the analysis. Other methods of filtration than with alundum are given for use in the absence of alundum ware.

(a) Provide a Spencer funnel (Fig. 64) or Sargent's alundum crucible-holder (Fig. 65). The latter is a modification of the Spencer funnel and may be used with any 60° funnel of suitable size. With the Spencer funnel the entire porous wall of the crucible may be thoroughly washed. The Sargent holder does not permit quite so thorough washing of the upper edge of the crucible, but, with care, the results are satisfactory. The funnel and

SECTION A-A
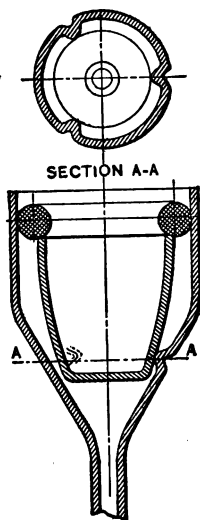
FIG. 64.
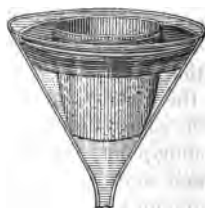
FIG. 65.

holder must be of the proper size, otherwise the crucible itself will trap the washings and prevent prompt filtration. A brass Spencer funnel may be readily made by one of the sugar-factory mechanics at a cost of a few cents, and is entirely satisfactory. The upper walls of the funnel must be parallel. The rubber rings are carried in stock by the dealers. These should be of pure soft rubber, and of about $\frac{1}{4}$ inch cross-section. The funnel is placed in a suction-filter-

ing device such as is shown in Fig. 66, or in a heavy Erlenmeyer flask with side tubule. The suction is obtained by a filter-pump or preferably through a pipe communicating with the vapor-pipe of the multiple-effect evaporator. The alundum [1] crucibles require a very efficient filter-pump on account of their large filtering area.

The alundum crucible should be thoroughly washed with hot water and be dried in the flame of a lamp preparatory to use. The oxides of copper or metallic copper should be
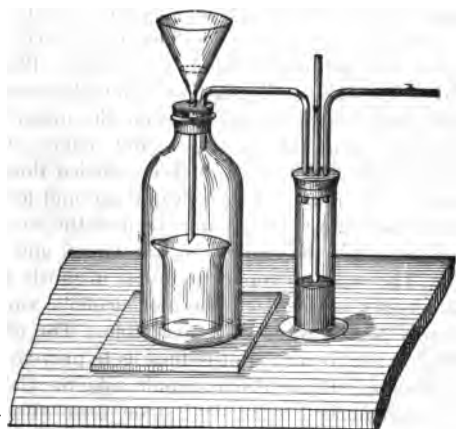
Fig. 66.

removed after use by solution in nitric acid and thorough washing with water.

Immediately after the reduction to suboxide of copper, this precipitate is collected in the alundum crucible and is thoroughly washed with hot water. The crucible should only be filled about half full during filtration. The suboxide distributes itself on the walls of the crucible. The washing may be followed by moistening the oxide and cru-

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[1] Alundum crucibles may be substituted for platinum in most of the analytical work of the factory and agricultural laboratories. These lose weight very slowly in glucose work, due to the action of the alkali. Correction can be made for the loss.

cible with pure alcohol to expedite the drying. Dry the crucible in an oven or cautiously over the flame of a lamp, according to the form in which the copper is ultimately to be weighed. Proceed by one of the following methods:

(b) *Wedderburn's Method of Reduction to Metallic Copper.*[1]— This is the simplest of the methods involving reduction to metallic copper and its results are nearly as accurate as those by electrolysis and equal to reduction in hydrogen. Bend the wires of a pipe-stem or silica triangle to form a tripod support for the alundum crucible. Place the tripod in a metal beaker or other convenient metallic vessel. Cover the bottom of the beaker to a depth of about 1 centimeter with alcohol. Denatured alcohol will serve. Place the beaker, covered with a watch-glass, on a hot plate and warm the alcohol until its vapors condense on the under side of the cover-glass. Heat the crucible to full redness, to burn off organic matter that may have been carried down with the cuprous oxide; remove it from the flame and let it cool until the redness almost disappears; remove the cover from the beaker and place the crucible on the tripod and replace the cover. The oxide of copper is almost instantly reduced to metallic copper in the atmosphere of alcoholic vapor and adheres firmly to the walls of the crucible. The object of cooling the crucible to very faint redness is to prevent setting fire to the alcohol. If the alcohol should take fire the flames are readily extinguished by blowing upon them after covering the beaker. The beaker should be removed from the hot plate a moment after introducing the crucible. It is necessary to let the crucible cool for three or four minutes in the vapor of alcohol, after the reduction to avoid re-oxidation of the copper. Should the crucible become quite cold, it should be moistened with pure alcohol and this be burned off. After cooling in a desiccator the crucible is weighed and the weight of copper is ascertained by difference. The whole operation consumes but five or six minutes and the copper plating is as good as that obtained by electrolysis.

Wedderburn's method may be conducted with a Gooch

[1] Journal Ind. and Eng. Chem. **7**, 610. Original method, Vladimír Stanek, Z. Zuckerind. Boehmen, **32**, 497; Votoček and Laxa, Abstract in Chem. Zeit. Chem. Repertorium, **21**, 324.

crucible, but the alundum ware is more convenient. An error may enter from occluded ash from the juice, but tests show this error to be very small and usually negligible. The calculation of the glucose is given farther on.

The Barthel alcohol-burner, Fig. 67, is suitable for heating crucibles.

(c) *Electrolytic Method in Nitric Solution.*—Collect the cuprous oxide in an alundum crucible as described in Wedderburn's method, except that a glass funnel must be used and the crucible need not be tared. After washing the oxide very thoroughly, change the receiving-vessel for the filtrate. Let 4 cc. of concentrated nitric acid fall drop by drop upon
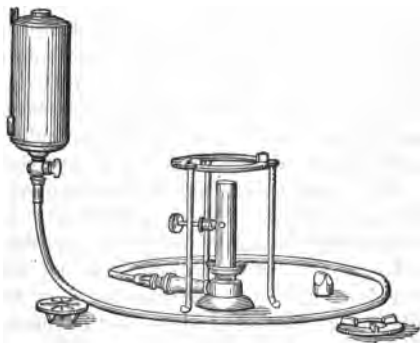
FIG. 67.

the oxide, being careful that all parts of the latter are wetted by the acid. Follow the acid with a jet of hot water from a wash-bottle and wash the walls of the crucible thoroughly. Should any of the red oxide remain, repass the acid filtrate through the crucible. The oxide may conveniently be reduced to metallic copper as in Wedderburn's method and this be dissolved instead of the oxide. Transfer the filtrate to a small beaker and dilute it to approximately 100 cc. Deposit the copper electrolytically upon platinum gauze as follows: Form a cylinder of 52-mesh platinum-gauze [1] 1 inch in diam-

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[1] Coarse copper-wire gauze would probably serve as a cathode. A copper cathode may be used in other electrolytic copper methods. The connection with the copper must be a platinum wire.

eter by 1.5 inch long. Connect the cylinder submerged in the solution with the positive pole of a battery or use the direct-lighting current reduced as will be described, and connect a platinum-foil anode with the negative pole, and electrolyze with a current of 10 amperes and 4 volts. The copper should be completely deposited upon the cylinder within 10 to 15 minutes.[1] Rotation of the anode during the reduction increases its rapidity. The solution should be tested for copper from time to time by withdrawing a drop and adding it to a little ammonia to neutralize the acid, then acetic acid to acidity and finally a drop of ferrocyanide of potassium solution, using a white porcelain plate to hold the solutions. When this solution no longer reacts for copper, i.e., does not turn brown when the ferrocyanide is added, without cutting off the electric current, withdraw the acid solution with a large pipette, at the same time replacing it with water. Repeat this operation until all the acid has been removed, then break the current, remove and dip the cylinder in pure alcohol and then in ether, and dry it in an oven for a few minutes. The current must not be discontinued so long as a trace of acid remains. The cylinder is now weighed, its increase of weight is due to the metallic copper deposited.

When the factory lighting-circuit is direct current, this may be regulated by an ordinary rheostat or by a simple home-made device (Fig. 68) and be used in the reduction to metallic copper.

Separate the twin wires M (Fig. 68) leading to an incandescent lamp, and connect them as is indicated in the figure with the regulator. The body of the regulator, C, is a glass tube nearly filled with water slightly acidulated with sulphuric acid. A is an insulated copper wire terminating in a platinum wire sealed in the tube C; B is a movable glass tube through which a copper wire extends; the lower end of the wire connects with a platinum wire E sealed into the tube and the upper end with a binding-post for connection with the lamp. The wire D leads to the anode or cathode of the electrolytic apparatus and A to the opposite pole. A small tube is passed through the cork in C for the escape

of the gases. The intensity of the current is regulated by the resistance of the incandescent lamp and the distance between the platinum points terminating A and E. A carbon filament lamp should be used. Usually a 16 C. P. carbon lamp or other lamp of about 50 to 60 watts capacity passes sufficient current for the deposition of the copper on a platinum dish.. If the copper does not deposit fast enough, increase the size of the lamp or approach the terminals A and E. If the copper does not deposit upon the dish or cylinder, with the current passing, reverse the connections B and D.

(c) *Electrolytic Method Using a Gooch Crucible.*—Filter and wash as directed in (a) but not using a tared crucible and making no effort to transfer all of the precipitate. Wash the asbestos film and the adhering cuprous oxide back into the beaker, using hot dilute nitric acid for this purpose. After the copper is all in solution, filter it through a Gooch crucible, using a thin asbestos film, and wash the filter thoroughly with hot water. Add 10 cc. of dilute sulphuric acid, containing 200 cc. acid of 1.84 specific gravity, per liter, to the filtrate, and evaporate it until the copper-salt has largely crystallized, then heat it carefully

Fig. 68.

on a hot iron plate or a sand-bath until the evolution of white fumes. Add 8 to 10 drops of nitric acid, specific gravity 1.42, to the residue and rinse it into a tared platinum dish of 100 to 125 cc. capacity. Precipitate the copper on the dish by electrolysis. Wash the copper thoroughly with water before breaking the current; remove the dish from the circuit, wash the copper with alcohol and ether successively and dry it over the open flame of a Bunsen burner at a temperature that can be easily borne by the hand. · Cool the dish and weigh it. A beaker may be substituted for the

platinum dish, the copper being deposited upon a platinum cylinder.

A Soxhlet filter tube, Fig. 69, may be used instead of the Gooch crucible. This filter consists of a tube of hard glass, 6 inches long, into one end of which is sealed a tubule 3 inches long, of convenient diameter for inserting in the stopper of a pressure filtering apparatus such as shown in Fig. 66. A perforated platinum disk A, A', Fig. 69, is sealed into the large tube, near the bottom, to support an asbestos-felt filter.
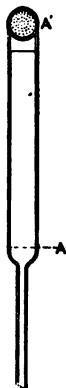
Prepare the filter-tube for use in the same manner as a Gooch filter and weigh it. Place a small funnel in the filter-tube to prevent the cuprous oxide from adhering to its walls, and moisten the asbestos-felt with water. Wash all of the precipitate onto the filter as described in (a). Dry the precipitate, then pass a current of pure dry hydrogen through it, at the same time gently heating the cuprous oxide with the flame of a Bunsen burner, until all of the oxide is reduced to the metallic state. Cool the copper in a current of hydrogen and weigh it. The weight of copper reduced may also be determined volumetrically by the methods of the various text-books.

FIG. 69.

Methods in which the Copper Oxide is Weighed.—The Wedderburn method of reduction to metallic copper and the electrolytic methods are more accurate than the methods involving the weight as an oxide. Of these latter methods, (a) should only be used for materials very free of organic matter other than the sugars. Method (b) when carefully conducted is almost as accurate as the Wedderburn or electrolytic methods. It is obvious that either alundum or Gooch crucibles may be used.

(a) Prepare a Gooch crucible to receive the precipitate by forming a very thick asbestos felt in it. Dry the crucible and felt in an oven or on a hot iron plate; cool and weigh the prepared crucible. Immediately after the reduction is completed, filter the contents of the beaker through the crucible, using a filter-pump, and wash the beaker and precipitate thoroughly, transferring all of the latter to the

filter. Care must be observed that neither suboxide of copper nor particles of asbestos pass into the filtrate. Follow the wash-water with a little alcohol, then with a few drops of ether. Place the crucible in a water-oven and dry it thirty minutes, then cool it in a desiccator and weigh it. The weight of the cuprous oxide$\times.888 =$ the weight of copper reduced.

(b) Collect the cuprous oxide in an alundum or a Gooch crucible and thoroughly dry it. Heat the oxide to full redness in a muffle furnace or in the oxidizing flame of a Bunsen burner. Continue the heating for about fifteen minutes. Cool the crucible in a desiccator and then weigh it as quickly as is possible. The cuprous oxide is oxidized to cupric oxide, which is very hygroscopic. The weight of cupric oxide$\times 0.8 =$ the weight of copper.

Calculation of the Percentage of Glucose by Meissl and Hiller's Method.—

Let $Cu =$ the weight of copper obtained;

$\quad P =$ the polarization of the sample;

$\quad W =$ the weight of the sample in the 50 cc. of the solution used for the determination;

$\quad F =$ the factor obtained from the table for the conversion of copper to invert-sugar;

$$\frac{Cu}{2} = \text{approximate absolute weight of invert-sugar} = Z;$$

$$Z\times\frac{100}{W} = \text{approximate per cent of invert-sugar} = y;$$

$$\frac{100P}{P+y} = R, \text{ relative number for sucrose;}$$

$$100 - R = I, \text{ relative number for invert-sugar;}$$

$$\frac{CuF}{W} = \text{per cent of invert sugar.}$$

Z facilitates reading the vertical columns; and the ratio of R to I, the horizontal columns of the table, for the purpose of finding the factor (F) for the calculation of copper to invert-sugar.

EXAMPLE. The polarization of a sugar is 86.4, and 3.256 grams of it (W) are equivalent to 0.290 gram of copper,

Then:
$$\frac{Cu}{2} = \frac{.290}{2} = .145 = Z;$$

$$Z \times \frac{100}{W} = .145 \times \frac{100}{3.256} = 4.45 = y,$$

$$\frac{100P}{P+y} = \frac{8640}{86.4 + 4.45} = 95.1 = R;$$

$$100 - R = 100 - 95.1 = I = 4.9:$$

$$R:I = 95.1:4.9.$$

By consulting the table it will be seen that the vertical column headed 150 is nearest to Z, 145, and the horizontal column headed 95:5 is nearest to the ratio of R to I, 95.1:4.9. Where these columns meet we find the factor 51.2 which enters into the final calculations:

$$\frac{CuF}{W} = \frac{.290 \times 51.2}{3.256} = 4.56 \text{ per cent of invert-sugar.}$$

MEISSL AND HILLER'S[1] FACTORS FOR THE DETERMINA-
TION OF MORE THAN 1 PER CENT OF INVERT-SUGAR.

Ratio of Sucrose to Invert-Sugar = R : I.	Approximate Absolute Weight of Invert Sugar = Z.						
	200 Milligrams.	175 Milligrams.	150 Milligrams.	125 Milligrams.	100 Milligrams.	75 Milligrams.	50 Milligrams.
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
0 : 10	56.4	55.4	54.5	53.8	53.2	53.0	53.0
10 : 90	56.3	55.3	54.4	53.8	53.2	52.9	52.9
20 : 80	56.2	55.2	54.3	53.7	53.2	52.7	52.7
30 : 70	56.1	55.1	54.2	53.7	53.2	52.6	52.6
40 : 60	55.9	55.0	54.1	53.6	53.1	52.5	52.4
50 : 50	55.7	54.9	54.0	53.5	53.1	52.3	52.2
60 : 40	55.6	54.7	53.8	53.2	52.8	52.1	51.9
70 : 30	55.5	54.5	53.5	52.9	52.5	51.9	51.6
80 : 20	55.4	54.3	53.3	52.7	52.2	51.7	51.3
90 : 10	54.6	53.6	53.1	52.6	52.1	51.6	51.2
91 : 9	54.1	53.6	52.6	52.1	51.6	51.2	50.7
92 : 8	53.6	53.1	52.1	51.6	51.2	50.7	50.3
93 : 7	53.6	53.1	52.1	51.2	50.7	50.3	49.8
94 : 6	53.1	52.6	51.6	50.7	50.3	49.8	48.9
95 : 5	52.6	52.1	51.2	50.3	49.4	48.9	48.5
96 : 4	52.1	51.2	50.7	49.8	48.9	47.7	46.9
97 : 3	50.7	50.3	49.8	48.9	47.7	46.2	45.1
98 : 2	49.9	48.9	48.5	47.3	45.8	43.3	40.0
99 : 1	47.7	47.3	46.5	45.1	43.3	41.2	38.1

[1] Zeitschrift, 1889, p. 735.
    NOTE.—Experiments show that this method may be used with a good degree of accuracy in the determination of *less than 1 per cent* of glucose in cane juices. (G. L. S.)

(2) *Gravimetric Method, using Soldaïni's Solution.*[1]—Place 100 to 150 cc. Soldaïni's solution (298) in an Erlenmeyer flask; boil five minutes; add a solution containing 10 grams of the material, previously clarified with lead if necessary, the excess of lead being removed with oxalate of potassium; boil five minutes. In boiling always use the naked flame. Having completed the reduction, remove the flask from the flame and add 100 cc. cold distilled water. Filter immediately through a Gooch crucible, and determine the copper in the precipitate by the electrolytic method, or collect the cuprous oxide in a filter-tube and reduce it as described on page 244. The weight of the metallic copper multiplied by 0.3546 gives the weight of the invert-sugar. It is claimed that this method is very exact, and that invert-sugar can be determined to within .01 per cent with certainty.

(3) *Gravimetric Determination of Sucrose and Glucose.*— Determine the glucose by the Meissl and Hiller method (1); invert the sucrose (89) and determine the combined invert-sugar and glucose by the reduction method given on page 188.

119. Determination of Reducing-sugars (Glu-cose). Volumetric Methods.—Volumetric methods of determining glucose are usually used in cane-sugar factories on account of their rapidity, but when very accurate results are required, the gravimetric methods are preferable.

If the analyses are always conducted under the same conditions of dilution, containing-vessel and method of heating, the results by the volumetric methods are comparable.

(1) *A Modification of Violette's Method.*—Transfer a definite weight of juice to a sugar-flask and clarify it with a solution of acetate of lead. Precipitate the excess of lead with oxalate of potassium in small excess and dilute the solution to 100 cc. Filter off the precipitate.

The calculations are simplified by the use of 5 grams, or a multiple of 5, of the juice in this test. A sufficient quantity of the juice should be used, if practicable, to give a burette-reading of approximately 20 in the titration about to be described.

The measurements of the standard solutions for this

process are most conveniently made with automatic burettes. Such a burette, designed by Squibb, is shown in Fig. 70. The burette is filled by suction applied at the mouth-piece shown at the end of the rubber tube. The reagent is drawn into the burette to a point a little above the zero-mark and the mouth-piece is released. The excess of the solution syphons back into the reservoir, leaving the burette filled to the zero-mark.

FIG. 70.

a   *b*
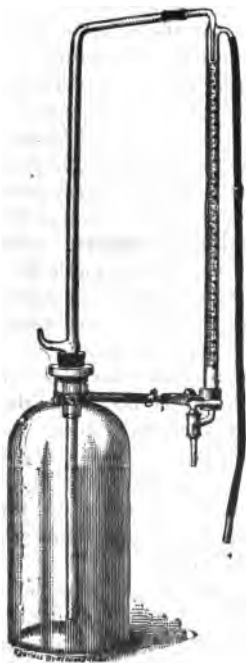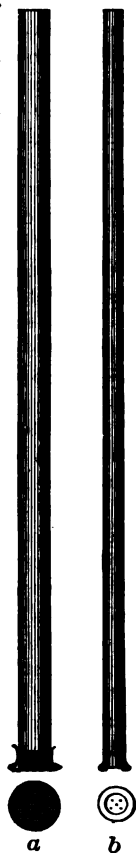
FIG. 71.

The test is made as follows: Measure 10 cc. of Violette's solution (296) into a large test-tube, 1.5 inches in diameter by 9 inches long, and dilute it with 10 cc. of water. Heat

solution to the boiling-point over the naked flame of a lamp, add a few cubic centimeters of the prepared juice, and boil two minutes. Repeat these operations until the blue color almost disappears, taking care to add the juice little by little as this point is approached and then only a drop or two at a time until the blue color disappears. After the first boiling of two minutes, it is only necessary to boil the liquid a few seconds, after each addition. A sand-glass is convenient for timing the first boiling. When the color just disappears, filter off a portion of the liquid to test for copper, using a Wiley or Knorr-Wiley filter-tube or other convenient filter.

Wiley's filter-tubes, Fig. 71, *a*, are made from pieces of glass tubing one-fourth inch bore by ten inches long. One end of the tube is softened in the flame of a lamp and then pressed against a block of wood to form a shoulder. A piece of washed linen is stretched over this end and tied in place. In using this tube the filter end is dipped into water in which is suspended finely divided asbestos, and by mouth-suction the linen is covered with a film of the asbestos. In Knorr's modification of this filter the tube is of small diameter and a perforated platinum disk takes the place of the linen, as indicated in Fig. 71, *b*. In using these tubes the solution is filtered through the asbestos film by mouth-suction and with the Wiley filter is poured from the tube into the test solution. With the Knorr filter the asbestos must be wiped off the end of the tube, and the liquid then expelled by blowing. The tubes should be dipped into very dilute nitric acid after use, and then be thoroughly washed with water.

Many chemists prefer to remove a drop of the solution and place it on a piece of end-reaction filter-paper. The precipitate remains in the center of the moistened spot, with the filtered solution around it.

In whatever way the filtered solution is obtained it must be tested for copper. This filtrate is acidulated with a 10-per cent solution of acetic acid and then a drop of a very dilute solution of ferrocyanide of potassium, 20 grams of the salt per liter of water, is added to it; a brown coloration indicates the presence of copper, and if this color appears,

more of the sugar solution be used. The juice must be added very carefully as the color test decreases in intensity until finally when all of the copper is reduced there will be no further coloration. The progress of the test may be readily followed, after a little practice, by noting the appearance of the precipitate and the color of the supernatant liquid.

The test should now be repeated, adding nearly enough of the sugar solution at once to reduce all of the copper; then proceed as before. The burette-reading should be made at the end of the operation. The calculation is made as follows:

Let W =the weight of juice in 1 cc. of the solution;

$\quad$ B =the burette reading;

$\quad$ x =the required per cent;

then $\qquad\qquad x = \dfrac{0.05 \times 100}{W \times B}.$

When W is .05 gram the formula reduces to $x = \dfrac{1 \times 100}{B}$, or x =the reciprocal of the burette-reading multiplied by 100.

A table of reciprocals is given on page 484 for use in these calculations.

If a multiple of 5 grams of juice is diluted to 100 cc. for this test, the reciprocal of the burette-reading multiplied by 100 is the same multiple of the per cent of glucose.

If 5 grams of juice in 100 cc. should give too strong a solution, dilute to 200 cc., 300 cc., etc., and multiply the reciprocal of the burette-reading by 200, 300, etc.

If the juice sample is measured instead of weighed, the table of reciprocals may still be used, but the value of x must be divided by the specific gravity of the juice. Pipettes on the principle of the sucrose pipette (**115**) may be used to measure the juice and obviate the necessity of dividing by the specific gravity or weighing the sample.

Violette's solution decomposes somewhat on standing. This may be avoided by preparing two solutions, one of the copper and the other of the alkali. In making a test 10 cc. of each of these solutions are used and the 10 cc. of water are omitted.

(2) *Soxhlet's volumetric method.* — Prepare the juice for analysis and make a preliminary test as described in (**1**), to

determine the approximate concentration, using Fehling's solution prepared according to Soxhlet's formula (297). Dilute the solution to a percentage of reducing-sugars between ½ and 1. Transfer 50 cc. of each of the solutions A and B to an Erlenmeyer flask or to a casserole, and add approximately the volume of the reducing-sugar solution required to precipitate the copper, basing this quantity on the preliminary titration. Heat to the boiling-point, then boil two minutes; test the solution for copper as described on page 249. If no reaction for copper is obtained, the sugar solution has either been added in excess or in just sufficient quantity for the reduction. Should copper still remain in solution, an additional portion of the sugar is required. In either case repeat these operations until two analyses are obtained differing by .1 cc. of the reducing-sugar solution, copper still remaining in one experiment and being completely precipitated in the other.

The calculations are based on the reducing power of dextrose as given below from Soxhlet's determinations.

100 cc. Fehling solution (equal parts A and B) require .4753 gram dextrose for the reduction of the copper. In Soxhlet's experiments the undiluted Fehling solution was employed, and the analyses were made under the conditions described in this article.

(3) *Sidersky's volumetric method, using Soldaini's solution.*[1]— Standardize the Soldaini solution by means of a solution of invert-sugar containing 5 grams of the sugar per liter. Proceed as in the gravimetric method given in page 247 (2), except that the end reaction is judged by the disappearance of the blue color instead of by the ferrocyanide test. The method as described, including the end-reaction test, is probably applicable, though Sidersky was guided solely by the disappearance of the color.

This method has the advantage of freedom from the sources of error, due to the sucrose, which are present in the older method of Violette. For highly colored products, such as molasses, etc., Sidersky has modified his method as follows: Dissolve 25 grams of the material

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[1] Traité d'Analyse des Matières Sucrés, D. Sidersky, p. 150.

in 100 co. water, add sufficient subacetate of lead [1] for clarification, dilute to 200 cc., mix, and filter. To 100 cc. of the filtrate add 25 cc. of a concentrated solution of carbonate of sodium; mix, and filter; of this filtrate take 100 cc., corresponding to 10 grams of the material, for the reduction. Boi! 100 cc. Soldaïni solution five minutes over a naked flame in an Erlenmeyer flask, then add the sugar solution, little by little, continuing the heating an additional five minutes. Remove the flask, add 100 cc. cold distilled water. collect the precipitate on an asbestos felt in a Gooch crucible, filtering under pressure. Wash the precipitate with hot water until the wash-waters are no longer alkaline. Three or four washings are usually sufficient. Add to the cuprous oxide 25 cc. normal sulphuric acid, i.e., the standardized acid, and two or three crystals of chlorate of potassium, and heat gently until the cuprous oxide is completely in solution. This operation should be conducted in a beaker or flask. Titrate the solution with a standard alkali solution, and determine by difference the volume of the acid used up, and from this volume the amount of copper reduced. It is preferable to use a half-normal solution of ammonia for this titration, letting the sulphate of copper act as the indicator. Prepare the ammonia solution as follows: Mix 200 cc. of commercial ammonia with 800 cc. of water. Determine the strength of this solution by titrating 25 cc., to which has been added 2 cc. of a concentrated sulphate of copper solution, against the normal sulphuric acid, adding the acid until the blue color disappears. Add sufficient water to the ammonia solution to make it one-half normal.

In making the titration proceed as follows: Cool the copper-sulphate solution resulting from the treatment of the cuprous oxide with sulphuric acid and chlorate of potassium; add 50 cc. half-normal ammonia solution. Titrate with the normal sulphuric acid. The blue color disappears with each addition of the acid, but reappears on stirring the solution as long as there is any ammonia which is not saturated. When all the ammonia is saturated, the color of the liquid

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[1] The lead should be removed by precipitation with potassium oxalate after acidulation with acetic acid (G. L. S.).

is no longer blue but a faint green. Note the burette-reading, which is equivalent to the copper precipitated. Each cubic centimeter of the sulphuric-acid solution is equivalent to .0137 gram of copper. Multiply the weight of copper by .3546 to obtain the weight of invert-sugar. To simplify the calculations multiply the burette-reading by .1124 to obtain the per cent invert-sugar.

120. General Remarks on the Determination of Glucose (Reducing-sugars).—Geerligs, Pellet, Edson and other chemists have shown that a part of the reducing-sugar is carried down with the lead precipitate when sub-acetate of lead is used in clarifying the solutions. The writer, acting on the suggestion of C. H. Gill,[1] used acetic acid to decompose the lead levulosate in optical work and Pellet and Edson afterward advised the use of acetic acid in glucose tests and also expressed a preference for the use of the normal acetate of lead in preparing solutions for both glucose and sucrose tests.

All traces of lead must be removed from the solution before proceeding with the reduction. Several deleading agents have been used by various authorities. As a result of an extensive series of experiments recently made for the author, in the interests of The Cuban-American Sugar Co., he has provisionally adopted oxalate of potassium or sodium or dry oxalic acid in deleading. Bornträger[2] states that sodium sulphate is preferable to the carbonate. The carbonate of sodium is very generally used in deleading and with very careful manipulation it may give good results. The experiments quoted, however, indicate that the oxalates or oxalic acid are preferable. It is advisable to use a little kieselguhr in conjunction with the oxalic acid or its salts to promote filtration. The experiments mentioned showed that the deleading agent may be added in advance of completion of the volume to the mark on the flask, provided the percentages of glucose are small. The filtration should not be immediate. Ample time must be allowed for the action of the deleading agent.

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[1] J. of the Chem. Soc., April, 1871.
[2] Zeit angew. Chem., 1892, 333.

121. Determination of the Ash.—*Carbonated Ash or Normal Ash.*—Dry 10 grams of juice in a shallow tared platinum dish, then incinerate the residue, first at a low temperature, and afterward at a dull-red heat. The weight of ash $\times 10 =$ per cent of normal ash.

In this determination the temperature should never rise above a low-red heat. As the ash consists largely of alkaline carbonates which quickly absorb moisture from the air, it should be cooled in a desiccator and be weighed as quickly as possible.

This incineration may be accomplished over the flame of a lamp, but it is preferable to use a muffle. An electric or gasolene muffle furnace should be used in the factory laboratory.

The carbonated ash is usually determined only in research work and not in commercial analysis. It is difficult to burn sugar or sugar-house products to obtain a large quantity of the carbonated ash for analysis. The usual method is conducted as follows: The material is heated in a large platinum dish until it takes fire and the flames burn out. It swells greatly and is difficult to confine to the dish. After the material has been sufficiently charred, it is transferred to a glass mortar and is rubbed to a powder. The powder is washed upon an ashless paper filter and is thoroughly extracted with hot water. The filtrate is reserved for further treatment. The filter and insoluble matter are returned to the platinum dish and are completely ashed. The filtrate is now evaporated to dryness in the platinum dish and the dish and contents are then heated to low redness to burn off any remaining organic matter.

Sulphated-ash.—Dry 10 grams of juice in a shallow tared fused silica or platinum dish. Add a few drops of pure concentrated sulphuric acid to moisten the residue and heat it carefully over the flame of a lamp. The acid renders the carbonized mass porous and converts the carbonates into sulphates.

When the charred mass ceases to swell, transfer the dish to a muffle heated to redness and burn off the carbon. The temperature may be higher than for the carbonated ash, but care must be observed not to fuse the ash.

the ash should be moistened with sulphuric acid and
then be reheated in the muffle to decompose sulphides.
The sulphides are formed in the reduction of the sulphates
in heating in the presence of carbon.

In the customary "sulphated-ash" method, one-tenth the
weight of the ash is deducted before calculating the per-
centage, to compensate for the formation of sulphates in-
stead of carbonates. This follows beet sugar usage. The
true correction is a very variable number and often approx-
imates 25 per cent. A correction factor should be determined
for each factory and each material. (*See* **136.**)

Muffle for Incinerations.[1]—A convenient muffle is shown
in Figs. 72, 73, 74, and is made as follows: A narrow
slot is cut the length of the bottom
of a French clay-muffle, Fig. 72,
a, b, holes are drilled in the walls
at c, d, Fig. 73, and heavy platinum
wires are inserted. These wires form
supports for a trough of platinum-
foil, Fig. 72, w, x, y, z, upon which
the dishes rest during the incinera-
tion. A hole is cut in the dome
of the muffle at t, Fig. 74. The
muffle is placed upon a suitable sup-
port and is heated by wing top
burners.

FIG. 72.

FIG. 73.

FIG. 74.

**122. Determination of the Total
Nitrogen and the Albuminoids.**
—*Total Nitrogen.*—The nitrogen is de-
termined by the moist combustion
method of Kjeldahl with modifica-
tions, as adopted by the association of Official Agricultural
Chemists.[2]

(1) *The digestion.*—10 cc. of the juice, dried in a small
capsule, are brought into a 550-cc. digestion-flask with
approximately .7 gram of mercuric oxide and 20 cc. of
sulphuric acid. The flask is placed on a frame in an in-
clined position, and heated below the boiling-point of the
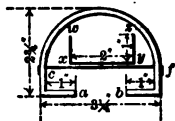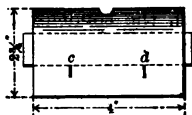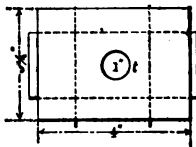
[1] Journ. Am. Chem. Soc. **16**, 151.
[2] Adapted from Bulletin 46, Div. Chem. U. S. Dept. Agric.

acid for from 5 to 15 minutes, or until frothing has cea.^{on}
If the mixture froths badly, a small piece of paraffine may
be added to prevent it. The heat is then raised until the
acid boils briskly. No further attention is required till
the contents of the flask have become a clear liquid, which
is colorless, or has only a very pale straw color. The
flask is then removed from the frame, held upright, and,
while still hot, potassium permanganate is dropped in care-
fully and in small quantity at a time, till, after shaking, the
liquid remains of a green or purple color.

(2) *The distillation.*—After cooling, the contents of the
flask are transferred to the distilling-flask with about 200 cc.
of water, and to this a few pieces of granulated zinc, pumice-
stone, or .5 gram zinc-dust, and 25 cc. of potassium-sulphide
solution are added, shaking the flask to mix its contents.
Next add 50 cc. of a saturated caustic-soda solution, free
from nitrates, or sufficient to make the reaction strongly
alkaline, pouring it down the side of the flask so that it does
not mix at once with the acid solution. Connect the flask
with the condenser, which should be of block tin, mix the
contents by shaking, and distil until all ammonia has passed
over into the standard acid. The first 150 cc. of the distillate
will generally contain all of the ammonia. This operation
usually requires from 40 minutes to one hour and a half.
The distillate is then titrated with standard ammonia, and
the calculations are made as usual. Previous to use, the
reagents should be tested by a blank experiment with sugar,
which will partially reduce any nitrates that are present
which might otherwise escape notice.

Albuminoid nitrogen,—The albuminoid nitrogen is deter-
mined by the following method of Stutzer, and the percent-
age of nitrogen is calculated to albuminoids by multiplying
by the factor 6.0.[1]

Prepare cupric hydrate as follows: Dissolve 100 grams of
pure cupric sulphate in 5 liters of water, add 25 cc. of glycerol,
and then a dilute solution of sodium hydrate until the

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[1] W. Maxwell, La. Expt. Sta. Bul. 38, 2d Series, p. 1375, advises the
use of the factor 6 instead of 6.25 as is customary by many plant-
analysts. He bases this factor 6 on a study of the composition of the
albuminoid matter of cane-juice.

liquid is alkaline; filter; rub the precipitate up with water containing 5 cc. of glycerol per liter, and wash by decantation or filtration until the washings are no longer alkaline. Rub the precipitate up again in a mortar with water containing 10 per cent of glycerol, thus preparing a uniform gelatinous mass that can be measured out with a pipette. Determine the quantity of cupric hydrate per cubic centimeter of this mixture.

Place 10 grams of the juice in a beaker, add 100 cc. of water, heat to boiling;[1] add a quantity of cupric hydrate mixture containing about 0.5 gram of the hydrate; stir thoroughly, filter when cold, wash with cold water, and, without removing the precipitate from the filter, determine nitrogen according to the method given for the determination of total nitrogen, adding sufficient potassium sulphid solution to completely precipitate all copper and mercury. The filter-papers used must be practically free from nitrogen. If the substance examined is rich in alkaline phosphates, add a few cubic centimeters of a concentrated solution of alum just before adding the cupric hydrate, and mix well by stirring. This serves to decompose the alkaline phosphates. If this be not done, cupric phosphate and free alkali may be formed, and the protein-copper precipitate may be partially dissolved in the alkaline liquid.

123. Acidity of the Juice.—Normal cane-juice is always acid. The acidity is usually expressed in terms of the number of cubic centimeters of decinormal alkali required to neutralize 100 cc. of the juice. The method of preparing a normal alkali solution, preferably caustic soda, is given on page 417. The decinormal solution is prepared from the normal by diluting 100 cc. of the latter to 1000 cc.

It is very difficult to note when neutrality is reached in using litmus paper as an indicator. If litmus paper is used it should be a very sensitive neutral paper. A few drops of logwood solution may be used as an indicator. The logwood assumes a purple or a violet color in the presence of an excess of the alkali. In making the titration it is convenient to proceed as follows: Measure 20 cc. juice

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[1] In the case of sorghum-cane juice, heat on a water-bath 10 minutes.

into a beaker or a porcelain dish and add a few drops
of logwood solution to it.   Measure into this juice the
one-tenth normal caustic-soda solution, little by little, with
constant stirring.   As the liquid approaches neutrality, test
a few drops of it from time to time in a separate dish, with
logwood solution.   Multiply the burette-reading at neutrality
by 5 and record the product as the acidity per 100 cc. of
juice in terms of decinormal alkali.

The above test is not required except in special inves-
tigations, or in control of the defecation.

124. Analysis of Clarified Juice.—The analysis of
the clarified juice is made by the same methods as that of the
normal juice.   If the carbonation process is used, which
is the case in very few factories, the juice must receive an
additional treatment with carbonic acid, after the first car-
bonation, and before the analysis, to precipitate all of the
lime it contains.

ANALYSIS OF THE SIRUP, MASSECUITES, AND MOLASSES.

SIRUP.

125. Analysis of the Sirup.—The tests usually required in the examination of a sirup are the density and the percentage of sucrose. In special investigations or in tracing inversion, glucose determinations are necessary and the sucrose should then be determined by Clerget's method, page 266.

The normal weight of sirup should ordinarily be used for the sucrose determination and this should be weighed and not measured with a sucrose or other pipette. The solutions for the polarizations should be acidulated with acetic acid, after clarification with subacetate of lead, but before filtration. Clarification with neutral acetate is to be preferred.

For the usual factory requirements the sirup may be analyzed by the methods described for the juice, except that the portions for the tests must be weighed.

MASSECUITES AND MOLASSES.

126. Determination of the Density.—The determination of the density of massecuites and heavy molasses presents certain difficulties which cannot readily be avoided and which compel the acceptance of numbers that are but more or less close approximations, according to the methods used.

As has been explained, the degree Brix of a solution is the percentage by weight of the pure sugar dissolved in it. But in the sugar industry it is usually considered to be the percentage by weight of solid matters, whether sugar or not, in solution. This implies that the solids other than sugar,

the non-sucrose, are of the same specific gravity as cane-sugar. This is practically true so far as regards the carbo-hydrate bodies, but is not for the inorganic salts which are associated with the sugars in the massecuites and molasses. These salts having such high specific gravity, as compared with the carbohydrates, influence the density determina-tions in a very marked degree.

Since the ratio of non-sucrose to the sucrose increases with each stage of the manufacture, as commercial sugar is removed, the difference between the apparent percentage of total solids, as indicated by the hydrometer, and the true percentage, as ascertained by actually drying the material, becomes larger.

It is evident from these remarks that calculations of the degree Brix or apparent total solids in massecuites and molasses, from the density of the product, must be accepted with caution and then only for comparative purposes when similar conditions of analysis are maintained.

There is another condition that has not yet been men-tioned. The density (Brix) of a solution calculated from spindling at one dilution is different from that calculated from the hydrometer number ascertained at another dilu-tion. Thus, for example, if one part of a final molasses be dissolved in two parts of water and this solution be spindled, the Brix of the molasses calculated from this spindling will be higher than it would be had one part of the molasses been dissolved in only one part of water. This difference is partly due to the contraction of the solution of sugar on dilution with water and partly to a similar contraction of the solu-tion of the salts in the molasses. This difference would be observed even though one were dealing with a pure sucrose solution instead of molasses. Obviously massecuites and molasses are too dense to be directly spindled, hence one must accept numbers obtained by dilution and spindling that are at best only comparative. The true solids of a final molasses may be from 5 to 10 per cent below the num-bers indicated by dilution and spindling.

The methods of dilution and spindling, given in this book, are those customarily used, and the results must not be considered absolute, but only as suitable for comparisons.

127. Specific Gravity.   Sidersky's Method.[1]—
This method is applicable to samples of massecuites boiled
blank and to molasses, but not to grained strikes.

The apparatus required is a 50-cc. sugar-flask, a suitable
heating arrangement, and a funnel with a glass rod for a
stopper.   Grind one end of the glass rod with moistened emery
into the funnel, to form a stopper.   Fill the funnel with a
sample of the massecuite or molasses, and set it in a cylin-
drical iron support, and heat carefully with the flame of a lamp.
The object of the iron cylinder is to distribute the heat.
When the material is quite warm, lower the stem of the funnel
into the flask, lift the glass rod and fill the latter to within
2 or 3 cc. of the mark.   Remove the funnel very carefully so
as not to smear the neck of the flask with molasses.   Keep
the sample hot a few minutes to facilitate the escape of the
air, then cool it to the room temperature by immersing the
flask in cold water.   Dry and weigh the flask and contents,
then reduce the temperature of the material to $17\frac{1}{2}°$ C.,
and run water into the flask on top of the molasses, to the
mark.   The calculations are shown in the following example:

Weight of flask and molasses. . . . . 91.570 grams
  "   "   "   empty. . . . . 25.275   "

  "   " the molasses. . . . . 66.295 grams

Weight of flask, molasses and water. . . . 94.672 grams
  "   "   "   "   and molasses . . . . 91.570   "

  "   " water (also its volume in cc.)   3.102 grams;

and $50 - 3.102 = 46.898$, the volume of the molasses; $66.295 \div
46.898 = 1.4136$, the required specific gravity at $17\frac{1}{2}°$ C.
By means of the table, page 482, we find the degree Brix
corresponding to this specific gravity to be 79.6°.

It is very difficult to make a correct test by this method
on account of the air-bubbles.   It is, however, the only
direct method for the specific gravity of massecuites and
heavy molasses that is used.

[1] Zeitschrift, 1881, p. 192.

128. Weight of a Unit Volume of Massecuite.—A modification of Sidersky's method described in the previous paragraph may be used to ascertain the weight of a certain volume of massecuite. The selection of the unit volume will, of course, depend upon whether the cubic foot or gallon or metric measures are used.

A device for making this measurement is shown partly in section in Fig. **75.** This consists of a cylindrical vessel of any convenient size and preferably of metal. The rim of the cylinders should be ground true, a strip of metal, CC', should be provided, which extends from side to side of the cylinder and supports a glass tube drawn to a capillary, as shown in TT'. Pins PP' in the rim of the cylinder and fitting in corresponding holes in the strip of metal insure replacing the latter always in the same position. Fill the cylinder to approximately the point w with massecuite, place the capillary-tube in position, then run in water from a burette very cautiously until the tube is reached. The instant the water reaches the tube it rises some distance into it by capillarity. This may readily be noted and more plainly if colored water is used. A previous determination of the volume of the cylinder to the bottom of the tube should be made with water. With this volume and that of the water required to complete the volume with the massecuite, that of the massecuite is readily ascertained and may be compared with the weight of the material.
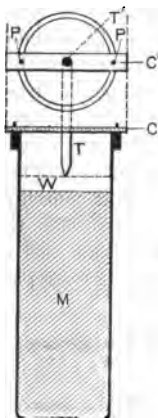
FIG. 75.

In making this test the massecuite should be of the temperature at which the measurements of this product are to be made in the factory, and correction for the expansion of the cylinder should be applied.

It is evident that this method cannot be used where vibrations of machinery are felt.

129. Apparent Degree Brix. Determination by Dilution and Spindling.—Dissolve a weighed quantity of

the material in an equal weight of distilled water. Transfer a portion of the solution to a cylinder and determine its degree Brix. Correct the degree Brix for the temperature error as described on page 222, and multiply the corrected number by 2 to ascertain the degree Brix of the material. This is the customary commercial and factory method. The true Brix or percentage of solids is usually several degrees lower than the apparent number by spindling.

130. Apparent Brix or Solids by Refractometer.— The method of using the refractometer has been described on page 225. When dilution and clarification of the sample are unnecessary this method gives results that closely approximate those by drying.

If the material contains crystals of sugar these must be dissolved, since the refractometer only indicates the solid matter that is in solution. When solution is employed the calculation is made as is indicated farther on in this paragraph. Dilution methods involve the contraction error of similar methods by spindling. The error may be reduced by working with very concentrated solutions. If a volume of water be added to a molasses solution, for example, the volume of the mixture is not the sum of the volumes, but is a smaller number, and the concentration is higher. It is, therefore, necessary as in hydrometer methods that the same definite conditions be observed that the results may be comparable.

In the event of testing a highly colored material, the method of Tischtschenko may be used. Mix the material with an equal weight of a solution of pure sucrose of known composition and of as high concentration as is practicable and determine the refractive index. Ascertain the percentage of solids in the mixture by means of the table on page 492. The percentage of solids in the material is ascertained by deducting the per cent of solids in the sucrose solution from twice the solids in the mixture. The principle of the method of calculation for other mixtures is the same as that of the dilution formulæ (207).

If necessary to dilute the material with water, the calculation is made as follows:

Let x = the required percentage of solids (Brix);
    W = weight of the material used;
      w = weight of the diluted solution;
then
    $Wx = bw$ and $x = bw/W$.

131. True Brix or Total Solids by Drying.—The method of Carr and Sanborn and the vacuum method (**112**) are recommended for this determination. In the latter method use 1 gram of the material. In both methods after weighing the material, dissolve it in a small quantity of distilled water in order to distribute it evenly over the pumice-stone. In Carr and Sanborn's method, dilute the sample in a weighing-bottle to a content of about 20 to 30 per cent of dry matter, using a weighed quantity of distilled water, and transfer a weighed portion of the solution containing about 1 gram of dry matter to the tared dish. Dry the sample and calculate the percentage, as directed in **112**, and note the remarks in the same paragraph in regard to the decomposition of levulose.

132. Determination of the Sucrose.—The method of determining the percentage of sucrose in a sample of molasses or massecuite depends upon the purpose of the analysis.

For the ordinary purposes of the factory, for the control of the various processes of manufacture, especially the vacuum-pan and crystallizer work, the absolute percentage of sucrose is not required. The relation, however, between the apparent per cent sucrose and the degree Brix, the coefficient of purity, is frequently needed, but not with a great degree of accuracy. The most important point in connection with this work is to adopt certain conditions of analysis and adhere to them with all similar materials, otherwise the results will not be comparable.

For the purposes of comparing the commercial sugar produced in the various periods of the crop and determining the total loss of sucrose, it is very essential that the final or commercial molasses samples be analyzed, using every precaution to avoid error and to obtain absolute results as

nearly as the processes of analysis will permit. In view of the above considerations methods for what may be termed " factory tests" and modifications of the Clerget process will be given:

Determination of sucrose, factory tests. — Dissolve the massecuite or molasses in water and dilute the solution to approximately 15° Brix. This is usually quickly accomplished after a little experience. Ascertain the degree Brix of the solution and proceed as in **115**, using the sucrose-pipette.

Horne's dry-lead method may be used in these tests, but it is usually advisable to modify the method slightly on account of the high levulose content of massecuites and molasses. Dilute the massecuite or molasses to between 15° and 16° Brix; add sufficient dry subacetate of lead for the clarification, being careful to use no more than is necessary. Also add a little dry sharp sand and mix thoroughly by shaking. The clarification is most conveniently effected in a small glass cylinder which may be covered by the palm of the hand while shaking. Filter and to 50 cc. of the filtrate, in a 50–55 cc. flask, add dilute acetic acid to acidity and make up to 55 cc. with water. Polarize this solution in a 200-mm. tube and increase the reading by one-tenth to compensate for the dilution. Refer to Horne's table, page 494, and under the polariscope reading and opposite the degree Brix find the coefficient of purity of the solution.

It is convenient to have a number of cylinders marked at approximately the 100-cc. point and to modify the method as follows: Fill the cylinder to the mark with the diluted massecuite or molasses; add a "struck" measure of the dry lead from a conical measuring spoon and a measure of sand; mix the contents of the cylinder by shaking and then add a measure of powdered oxalic acid (dry) and another of kieselguhr. The quantity of acid must be insufficient for the precipitation of all the lead. Shake, filter and polarize. Find the purity by Horne's table, page 526. The table should be extended to cover a wider range of densities at the places most used.

The coefficient of purity is all that is usually required in these tests. It should be noted that on account of the large

dilution of the material the coefficient is lower than it would otherwise be.

133. Clerget's Method for Sucrose.—This is often termed the "double-polarization method," since two polarizations are made, one before and the other after inversion, in order to eliminate the influence of the invert-sugar that may be present. Cane-sugar products usually contain the three sugars, sucrose (+), dextrose (+) and levulose (−). The direct polarization is therefore the resultant of the polarizations of these three sugars.

In the original Clerget method, 50 cc. of the sugar solution are inverted by the addition of 5 cc. of concentrated hydrochloric acid in a 50–55-cc. flask, with heating to 68° C. during fifteen minutes, followed by rapid cooling. This method requires the use of Clerget's constant, 144. The calculations are made as in the following modifications of the method. The modifications described in the following pages are those usually used in cane-sugar work. All the modifications have been devised with a view to reducing the risk of error through decomposition of levulose or to simplify the work.

134. Clerget's Method. Herzfeld's (Official German) Modification.—The instructions given here are modified slightly from those of Herzfeld to meet cane-sugar factory conditions: Dissolve 65.12 grams of massecuite or molasses in water, contained in a 500-cc. (Mohr) flask, or 65 grams if a true cc. flask is used. Add subacetate of lead for clarification, dilute to the mark, mix and filter. To 50 cc. of the filtrate contained in a 50–55 cc. flask add acetic acid to acidity and dilute to 55 cc. Polarize this solution, noting the temperature, and reduce the reading to terms of a 200-mm. tube and a normal solution. Correct for the dilution to 55 cc., increasing the reading by 1/10. Enter this number as the direct polarization.

Delead a portion of the original filtrate by the addition of dry sodium oxalate.[1] It is not necessary that all the lead be removed in deleading, but the quantity left should be very

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[1] Cross recommends the use of dry oxalic acid as a deleading agent in preparing for both the direct and invert polarizations. If this is used in excess of the quantity required to precipitate the lead, the filtration may be difficult. La. Expt. Sta. Bul. 135, p. 29.

small. Filter and measure 75 cc. of the filtrate into a 100-cc.
flask and add 5 cc. of concentrated hydrochloric acid of
1.188 sp. gr. Mix the contents of the flask by a circular
motion, place the flask in a water-bath heated to about 72°
C. and insert a thermometer. Heat the bath, so adjusting
the temperature that the solution in the flask shall reach a
temperature of 69° C. in two and one-half to three minutes
and continue the heating during a total period of ten min-
utes. The contents of the flask should be mixed from time
to time to insure a uniform temperature. The bottom of the
flask should not rest upon the bath, but upon a suitable
rack. At the conclusion of the heating-period, plunge the
flask into cold water and cool the solution to about the room
temperature. Wash the solution from the thermometer into
the flask and complete the volume to 100 cc. at the tem-
perature of the direct polarization. If the invert-sugar solu-
tion is too dark-colored it should be treated with successive
small portions of metallic zinc-dust after completion of the
volume. The coloring-matter is destroyed by the nascent
hydrogen. No more zinc than is necessary should be used.

Make the invert polarization, using a Landolt inversion-
tube, Fig. 36. Circulate water of the temperature of the
direct polarization through the water-jacket of the tube
during the operation. Note the polariscope-reading (minus)
and ascertain the temperature by inserting an accurate
thermometer, graduated to $\frac{1}{4}$° C., into the solution through
the side tubule. Reduce the polariscope-reading to terms of
a normal solution observed in a 200-mm. tube. If the steps
indicated have been followed, including deleading with a
dry salt, multiply the observed reading by 2.67 to effect the
reduction.

The calculation of the per cent sucrose is made by the
following formula, in which S is the algebraic difference
between the direct and the invert polarizations and t is the
temperature of the invert observation: Per cent sucrose in
the material $= \dfrac{100S}{\text{Constant} - 0.5t}$.

The constant varies with the concentration, and, according
to Herzfeld is 142.66 for a solution containing in 100 cc., the
quantity of invert-sugar that 13 grams of sucrose will pro-

duce. Prof. Herzfeld requested the International Committee (New York Meeting of the International Congress of Applied Chemistry) to revise his table of constants, as several investigators have reported apparently high results in its use. Steuerwald [1] has shown that Herzfeld's constants give high results and has redetermined these numbers and published them in the following convenient table:

STEUERWALD'S TABLE OF CONSTANTS.
(Herzfeld's Inversion Method).

Invert Reading in 200-mm. Tube.	Temperature of the Observation $= t$.					
	20° C.	22° C.	24° C.	26° C.	28° C.	30° C.
−25	143.51					
−24	143.45	143.43				
−23	143.39	143.38	143.36			
−22	143.34	143.30	143.32	143.29		
−21	143.28	143.26	143.24	143.23	143.21	143.20
−20	143.23	143.20	143.18	143.16	143.15	143.14
−19	143.17	143.15	143.12	143.10	143.09	143.07
−18	143.12	143.09	143.06	143.04	143.02	143.01
−17	143.06	143.03	143.00	142.98	142.96	142.94
−16	143.01	142.98	142.95	142.92	142.90	142.88
−15	142.95	142.92	142.89	142.86	142.83	142.81
−14	142.90	142.86	142.83	142.80	142.77	142.74
−13	142.84	142.80	142.77	142.74	142.71	142.68
−12	142.79	142.75	142.71	142.68	142.64	142.61
−11	142.73	142.69	142.65	142.61	142.58	142.55
−10	142.68	142.64	142.59	142.55	142.52	142.48
− 9	142.62	142.58	142.53	142.49	142.45	142.42
− 8	142.57	142.52	142.47	142.43	142.39	142.35
− 7	142.51	142.46	142.41	142.37	142.33	142.29
− 6	142.46	142.41	142.36	142.31	142.26	142.22
− 5	142.40	142.35	142.40	142.25	142.20	142.15
− 4	142.35	142.29	142.24	142.19	142.14	142.09
− 3	142.29	142.24	142.18	142.13	142.07	142.02
− 2	142.24	142.18	142.12	142.06	142.01	141.96
− 1	142.18	142.12	142.06	142.00	141.94	141.88

The sucrose is calculated by Herzfeld's formula, using Steuerwald's constants as follows: Select a constant corresponding to the invert polariscope-reading and temperature and substitute this for "constant" in the formula. Since the invert-reading is always minus in cane-sugar work,

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[1] Archief., 1913, 21, 1383; Int. Sugar Journ., 1914, 16, 82.

divide the sum of the direct- and invert-readings by the constant minus half the temperature in centigrade degrees and multiply the quotient by 100. Example: Direct polarization, 30.4; invert-reading, -17.9; temperature, 24° C. The constant corresponding to -17.9 at 24° is 143.06, therefore substituting these values in the formula: Per cent sucrose

$$= \frac{30.4 + 17.9}{143.06 - 12} = \frac{48.3}{131.06} = 36.85.$$

The inversion may be conducted at the room temperature. The inversion is always complete within twenty-four hours at a temperature above 20° C. and in fact when there is certainty that the temperature is always above 20° a period so short as sixteen hours is sufficient. The twenty-four-hour period is usually the most convenient. From this it appears that, when time is available, the tedious inversion with heating may be avoided and with certainty of freedom from destruction of levulose. The convenient special inversion flask shown in Fig. 76 eliminates pipette measurements in this modification of the

FIG. 76.

method. The body of the flask serves to measure the sugar solution, the middle section is for the acid and the top mark completes 100 cc.
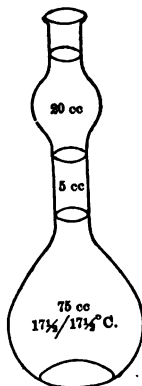
135. Clerget's Method as Modified by Steuerwald.[1]—The inversion is conducted at room temperature with increased acid strength. A special table of constants is required.

Prepare the solution as described in the preceding paragraph. Measure 50 cc. of the filtrate into a 100-cc. flask and add 30 cc. of hydrochloric acid of 1.1 sp. gr. (acid of 1.188 sp. gr. diluted with an equal volume of water). Set aside three hours if the temperature is between 20° and 25° C. or two hours if above 25° C. Dilute the solution to 100 cc. and polarize, observing the same temperature conditions as have been described in the preceding paragraph. The

[1] Archief., 1913, 21, 831; Int. Sugar Journ., 1913, 15, 489.

following table of constants must be used in connection with the Herzfeld formula. The readings should be reduced to terms of the normal weight of the material in 100 cc. of solution before making the calculations:

STEUERWALD'S TABLE OF CONSTANTS.

(Inversion at room temperature with 30 cc. acid.)

Invert-Reading in 200-mm. Tube.	Temperature of the Observation $= t$.						
	32° C.	30° C.	28° C.	26° C.	24° C.	22° C.	20° C.
−18	....	....	....	....	....	145.51	145.54
−17	....	....	....	145.39	145.42	145.46	145.49
−16	....	145.27	145.30	145.34	145.37	145.41	145.44
−15	145.18	145.22	145.25	145.28	145.32	145.35	145.39
−14	145.12	145.16	145.19	145.23	145.26	145.30	145.34
−13	145.06	145.10	145.13	145.17	145.21	145.25	145.29
−12	145.00	145.04	145.08	145.12	145.16	145.20	145.24
−11	144.94	144.98	145.02	145.07	145.11	145.15	145.19
−10	144.88	144.93	144.97	145.01	145.06	145.10	145.14
− 9	144.82	144.87	144.91	144.96	145.00	145.05	145.10
− 8	144.77	144.81	144.86	144.90	144.95	145.00	145.05
− 7	144.71	144.75	144.79	144.84	144.90	144.95	145.00
− 6	144.65	144.70	144.74	144.79	144.84	144.89	144.95
− 5	144.59	144.64	144.69	144.74	144.79	144.84	144.90
− 4	144.53	144.58	144.63	144.68	144.74	144.79	144.85
− 3	144.47	144.52	144.58	144.63	144.69	144.74	144.80
− 2	144.41	144.46	144.52	144.58	144.63	144.69	144.75
− 1	144.35	144.41	144.46	144.52	144.58	144.64	144.70

136. Determination of the Ash.—Proceed as is directed in **121**, except use from 2 to 3 grams of the material. The burning to normal ash is facilitated by dissolving the material in diluted alcohol and then incorporating 50 mg. of zinc oxide, the weight of which must be deducted from the ash before the calculations. Or, incinerate with benzoic acid. Dissolve 25 grams of the acid in 100 cc. of 90 per cent alcohol. Moisten the sample with water and then caramelize it at a low heat. Add 2 cc. of the benzoic solution and, after evaporating the alcohol, incinerate at incipient red heat in the muffle furnace.

For sulphated-ash proceed as is described in paragraph **121**. From 3 to 5 grams of the material is a suitable quantity for the test.

137. Acidity and Alkalinity. Qualitative Tests.— Solutions of massecuites and molasses are usually so dark-

colored that the usual tests for acidity or alkalinity cannot
be made. Buisson [1] advises the following method: Trans-
fer 25 cc. of a solution of the material to a glass-stoppered
flask; add one drop of neutral corallin solution and 10 cc.
of washed ether. Agitate thoroughly and then wait a few
seconds for the ether to separate and rise to the surface. The
slightest excess of acid or alkali reacts upon the corallin
and changes its color to a yellow or red as the case may be.
The water used in dissolving the material must be distilled
and the ether must be neutral.

In the experience of the author the success of this method
depends largely upon the quality of the corallin. He uses
the alcohol soluble corallin as prepared for staining in micros-
copy. Instead of one drop of the solution he uses several
drops of the corallin dissolved in alcohol.

**138. Estimation of the Crys-
tallized Sugar in Massecuite.**
—*Karcz Method.*[2]—This method, as
applied to raw sugar will be first de-
scribed, then its application to a masse-
cuite: Weigh 30 to 50 grams of raw
sugar and transfer it to a glass dish con-
taining an equal weight of pure anhy-
drous glycerine. Mix the sugar and
and glycerine intimately with a glass
rod, and place the dish in a desiccator
over fused calcium chloride or strong
sulphuric acid. Repeat the mixing
from time to time until the crystals are
well separated and the molasses uni-
formly distributed in the glycerine
solution. This preparatory work re-
quires fifteen minutes and upwards.
Place a plug of dry filtering-cotton in
the funnel of the apparatus shown in
Fig. 77; transfer the mixture to the
funnel and replace the cover. Filter
off the glycrine solution, using a filter-
pump. The mixture should be protected from the moisture
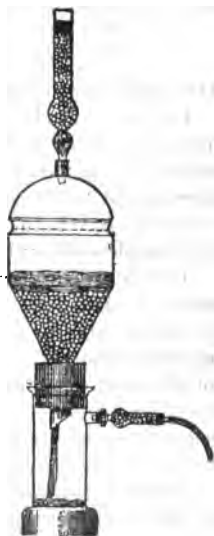
FIG. 77.

[1] Bulletin de l'Association des Chimistes de France, **9**, 597.
[2] Zeit. Rubenzucker-Industrie, **31**, 500.

of the air during filtration by a chloride of calcium tube, as shown at the top of the funnel-cover in the figure.

Since the anhydrous glycerine absorbs moisture with great rapidity, its contact with moist air should so far as possible be avoided.

Polarize the normal weight of the glycerine filtrate as obtained above and calculate the crystallized sugar by the following formulæ: [1]

$x =$ sucrose in the molasses attached to the crystals;

$P =$ per cent sucrose in the raw sugar;

$p =$ per cent sucrose in the glycerine filtrate;

$x = \dfrac{200 - P}{100 - p} p$ and $P - x =$ the percentage of crystallized sugar.

EXAMPLE.—Polarization of the raw sugar $= 95.6$; polarization of the filtrate $= 6.75$.

$$x = \frac{200 - 95.6}{100 - 6.75} \times 6.75 = 7.55; \quad \text{and} \quad 95.6 - 7.55 = 88.05$$

the percentage of crystallized sugar.

In view of the large proportion of glucose usually present in cane products, to apply the method to masse-cuites the sucrose x, P, and p, in accurate work, should be ascertained by the modified Clerget method, page 266. This is not the case in the following modification of Karcz' method by Perepletchikow: [2]

Transfer the normal weight of the massecuite, treated with an indefinite quantity of anhydrous glycerine, as described above, to Karcz' apparatus and filter off the glycerine solution. Wash the crystals with repeated portions of glycerine until the filtrate is no longer colored. Remove the funnel from the apparatus and wash the crystals into a sugar-flask and polarize them. The polariscope reading is the percentage of crystals in the massecuite.

Dupont's method.[3]—This method usually requires double polarization with cane products.

[1] Zeitschrift j. Zuckerindustrie Bohem, Jan., 1895.

[2] Zapiski, 1894, 18, 346.   Bul. Association des Chimistes, 12, 407.

[3] Manuel-Agenda des Fabricants de Sucre, Gallois et Dupont, 1891, p. 293.

Heat a quantity of massecuite of known polarization, for example 500 grams to 85° C., and purge the sugar in a small centrifugal, such as is shown in Fig. 87. The sieve of the centrifugal should be covered with thin flannel. Dry the sugar as thoroughly as possible by means of the centrifugal. Polarize the massecuite, the crystals and the molasses. Calculate the percentage of crystals by the following formula:

Let $x =$ the weight of crystallized sucrose in one part of massecuite;

$a =$ polarization of the massecuite;

$p =$ polarization of the crystals;

$p' =$ polarization of the molasses.

$\therefore x = \dfrac{a - p'}{p - p'}$, and $100x =$ the crystallized sucrose in 100 parts of massecuite.

EXAMPLE.

Let $a = 84.5$;

$p = 100$;

$p' = 60.6$.

$\therefore x = \dfrac{84.5 - 60.6}{100 - 60.6} = 0.6066$ and $100x = 60.66$, the percentage of crystals in the massecuite.

138a. Determination of the Glucose.—Proceed as is described in paragraph **118.**

ANALYSIS OF SUGARS.

139. Polarization.—Weigh the normal weight of the sugar in a nickel capsule. Add sufficient water to moisten the sugar, waiting a moment for the water to penetrate the mass. The moist sugar may usually be poured slowly into a narrow-neck 100-cc. flask without difficulty. A little practice is necessary to accomplish this expeditiously. If difficulty is experienced, a special funnel of nickel (*see* page 165) should be inserted and extend just into the body of the flask. The sugar may be readily washed through the funnel. The capsule, funnel and neck of the flask must be washed with a jet of water. Care should be observed not to use more than about 60 cc. of water in these operations. The flask should be well cleaned before use (*see* page 169) to prevent water from adhering to the neck. Dissolve the sugar by imparting a rotary motion to the flask. Hold the flask above the level of the eye ocasionally to see whether all the crystals are in solution. It is essential that no sugar be left undissolved before proceeding to the clarification.

Having dissolved the sugar, add from 0 to 8 cc. of subacetate of lead (54.3°), the quantity depending upon the grade of the sugar. White sugar requires no lead, but should usually receive a little alumina cream to facilitate filtration. High-grade centrifugals require from 1 to 2 cc. and low sugars, according to their grade, up to about 8 cc. of the lead solution. After mixing the sugar and lead solutions add about 2 cc. of alumina-cream (**292**) and complete the volume to 100 cc., washing down the neck of the flask. If foam interferes with this operation it should be broken down with a drop of ether. The water should be of the temperature of the polariscope room and the flask should be held by the upper part of the neck during the manipulations, to prevent warming the solution. If drops of water adhere to the neck of the flask they should be absorbed by a strip of filter-paper.

Having finished these operations, cover the mouth of the

flask with the thumb and mix the solution thoroughly by violent shaking. Pour the entire contents of the flask upon a folded filter in a stemless funnel (80). Rinse the receiver with the first portions of the filtrate and in all reject fully 10 cc. of the filtrate. The first of the filtrate contains the moisture displaced from the filter paper. The filtration will be rapid and the filtrate bright if the proper amount of lead subacetate has been used. Should the filtrate be cloudy, the whole operation should be repeated, changing the quantity of lead rather than attempt to clear the solution by refiltration. The funnel should be so large that the paper will not project above it and during the filtration it should be covered.

The polarization is made as is usual. The polariscope should be tested with a standardized quartz plate before and after use, and the reading should be corrected if need be. The cover-glasses should be carefully selected and be free of flaws and scratches. The paragraphs (83-86) relative to the influence of clarifying agents and temperature should be consulted.

Dr. W. D. Horne's dry-lead method may be used with high-grade sugars. After dissolving the sugar, dilute the solution to 100 cc. and add sufficient dry subacetate of lead for clarification, carefully avoiding the use of more than is necessary. Also add a little dry sand to break up particles of lead precipitate that might occlude sugar solution. Close the flask with the thumb and shake it vigorously to mix its contents. Filter and polarize as has been described.

140. Clerget's Method for Sugars.—Proceed as has been described in paragraphs **134, 135,** except use 50 cc. of a deleaded sugar solution containing the normal weight of sugar in 100 cc., in the inversion.

The following analyses of Cuba sugars indicate the differences that may be expected between the direct and the Clerget polarizations:

	Direct Polarization	Clerget.
Cuba centrifugal sugar............	96.65	97.22
Cuba centrifugal sugar............	95.3	95.9
Cuba 89° refining sugar..........	86.2	87.57
Standard granulated (Control test)	99.75	99.76

141. Determination of Glucose.—The method to be selected depends upon the percentages of sucrose and glucose in the sample. A modification of Herzfeld's method should be used for sugars polarizing above 99°. The Meissl and Hiller method, page 236, should be used for sugar containing more than 1 per cent of glucose.

Method for Sugars Polarizing above 99°.—Dissolve 40 grams of sugar, contained in a 200 cc. flask, in water, add normal lead acetate solution for clarification, dilute to the mark, mix and filter. Add dry sodium oxalate to the filtrate for deleading and refilter. If preferred, the lead may be precipitated by potassium oxalate solution before diluting to 100 cc. and thus one filtration may be avoided.

Measure 50 cc. of Soxhlet's solution, *i.e.*, 25 cc. of the copper solution and 25 cc. of the alkali (297) into a 400 cc. beaker and add 50 cc. of the deleaded sugar solution. Heat the mixture to boiling, taking about four minutes to reach this temperature and continue the boiling exactly two minutes. At the conclusion of the heating add 100 cc. of cold recently boiled distilled water to the contents of the beaker and then immediately filter off the cuprous oxide in a Gooch or an alundum crucible and proceed by one of the methods described in **118.** The percentage of glucose is ascertained from the following table by inspection:

HERZFELD'S TABLE FOR THE DETERMINATION OF IN-
VERT-SUGAR IN MATERIALS CONTAINING 1 PER CENT
OR LESS OF INVERT-SUGAR AND MORE THAN 99 PER
CENT SUCROSE.

Copper reduced by 10 Grams of Material.	Invert-Sugar.	Copper reduced by 10 Grams of Material.	Invert-Sugar.	Copper reduced by 10 Grams of Material.	Invert-Sugar.
Milligrams.	Per cent.	Milligrams.	Per cent.	Milligrams.	Per cent.
50	0.05	120	0.40	190	0.79
55	0.07	125	0.43	195	0.82
60	0.09	130	0.45	200	0.85
65	0.11	135	0.48	205	0.88
70	0.14	140	0.51	210	0.90
75	0.16	145	0.53	215	0.93
80	0.19	150	0.56	220	0.96
85	0.21	155	0.59	225	0.99
90	0.24	160	0.62	230	1.02
95	0.27	165	0.65	235	1.05
100	0.30	170	0.68	240	1.07
105	0.32	175	0.71	245	1.10
110	0.35	180	0.74		
115	0.38	185	0.76		

142. Estimation of the Moisture.—The moisture is driven off by drying in an oven. The temperature at which the operation is conducted depends upon the character of the sugar. If the sugar is of low grade, such as a molasses sugar, the temperature should not rise above 100° C. and in fact such sugars should be dried in vacuum. Modern raw-sugar factories now produce little low-grade product, hence the temperature of drying may usually be comparatively high. A sugar of large crystal should be dried at 105° C. and exceptionally high-test sugars may even be heated to 110° C. Large crystals are liable to occlude moisture that is not driven off until a temperature of 105° C. is reached. A drying period of three hours for 2 to 3 grams of sugar spread evenly over the bottom of a broad shallow dish is usually sufficient.

Low-grade sugars, in the absence of a vacuum-oven, should receive a preliminary drying in a water-oven and after two or three hours should be transferred to an air-oven and be dried for a short period at 105° C. Pellet recommends conducting a parallel test with granulated sugar, moistened with the estimated percentage of water that the sample contains. When the granulated sugar ceases to lose moisture both samples are considered dry. The dried sugar should be cooled in a desiccator preparatory to weighing.

143. Determination of the Ash.—The sulphated-ash method as described on page 270 for massecuites is used in both factory and commercial testing.

144. Iron in Sugars. Sulphide Colorimetric Method.[1]—Prepare a stock solution containing 10 grams of pure crystallized ferrous sulphate, $FeSO_4 \cdot 7H_2O$, dissolved in a 50–60 per cent pure sucrose solution, with the addition of a few drops of sulphuric acid, and dilute to 1000 cc. with the sugar solution. The acid should be very largely diluted before adding it to the sugar solution.

Dilute this stock solution with distilled water, from time to time as required, e.g., 10 cc. to 100 cc. and 50 cc. of this solution to 500 cc.

The tests are made in Nessler's cylinders, a number of

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[1] Eastick, Ogilvie and Linfield, Int. Sugar Journ., 14, 428.

which of the same diameter and height should be provided. Into a series of these cylinders measure increasing amounts of the diluted stock solution, noting the quantity of iron in each, and dilute each to 100 cc. Add 2 cc. of recently prepared monosulphide of ammonia to each and stir. Dissolve 3 to 10 grams of the sugar in a Nessler's cylinder, dilute the solution to 100 cc. and add 2 cc. of the sulphide solution. Let the cylinders stand ten minutes and then match the color of that including the sample with one of those containing the stock solution. Both then contain the same quantity of iron, *i.e.*, the quantity of iron in the sugar used. The cylinders should stand on white paper in making the comparisons.

The sulphide is prepared by saturating ammonium hydroxide with sulphureted hydrogen and then adding an equal volume of ammonium hydroxide.

In the case of dark sugars, incinerate the sugar, with the addition of iron-free sulphuric acid, burning at the lowest possible temperature. Dissolve the ash in a minimum quantity of iron-free hydrochloric acid and proceed with this solution as has been described.

145. The Dutch Color Standards.—Foreign sugars, on entering certain countries, pay duty according to their polarization and color. If their color is No. 16 Dutch standard, e.g., or lighter, they pay a higher rate of duty than if darker than this standard.

The Dutch color standards consist of a set of samples of sugar numbered up to 20, which is white sugar. These are prepared by an establishment in Holland and are supplied the sugar trade in sealed bottles. The samples should be renewed from time to time, since the color of the sugar is not permanent.

Centrifugal 96° sugar will usually be darker than No. 16, especially when molasses is boiled in with the first sugar. The chemist of a tropical sugar factory should be supplied with a sample of No. 16, so as to avoid the shipment of sugar of this color or lighter to certain countries and consequent loss to the factory-owners.

146. Rendment.—The rendment is the estimated yield of refined sugar that a raw sugar will produce. This esti-

mate is based upon refining experience and is calculated variously in different countries and for sugars of different origin. The American refiners deduct five times the percentage of ash from the polarization of the raw sugar to obtain the percentage of rendment, or the " analysis" of the sugar.

147. Preparation of the Sample.—The sample of press-cake obtained as directed in **104**, should be reduced to small fragments and mixed by means of a spatula or large scissors. If the cake is very soft it may be necessary to rub it to a paste in a large mortar, then subsample it. With good cane and careful management the press-cake will be firm and the sample may be readily reduced.

148. Moisture Determination.—Dry 5 grams of the press-cake, in a shallow tared dish, to constant weight in a water-oven at approximately 100° C. The loss of weight $\times$ 20 = percentage of moisture.

The sample should be partly dried at a low temperature before heating the oven to 100° C., otherwise the surfaces of the fragments of press-cake may be covered with a glazed coating which would prevent the escape of moisture. It would be convenient in all open-dish dryings of sugar-house materials to have two ovens, one heated to a low temperature and the other to the final temperature.

149. Sucrose Determination.—Transfer 25 grams of filter-press cake to a small mortar. Add boiling hot water to the sample and rub it to a smooth cream with the pestle. Wash the material into a 100-cc. flask with hot water, cool, add 6 cc. subacetate of lead solution (54.3° Brix), complete the volume to 100 cc., mix the contents of the flask thoroughly, filter, and polarize. The polariscope reading is the percentage of sucrose in the press-cake.

It is usually more convenient to use 50 grams of the sample, and add the subacetate of lead while rubbing the material to a cream and wash all into a 200-cc. flask. This facilitates the removal of the last portions of the press-cake from the mortar. A flask with the neck enlarged above the gradua-

tion is more convenient in this analysis than an ordinary
sugar-flask (Fig. 78).
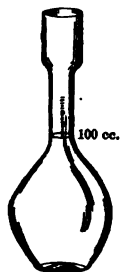
The object in using 25 grams of the material
in this analysis instead of the normal weight
is to correct for the volume of the lead pre-
cipitate and that of the insoluble matter.

Parallel experiments, on a sample of filter-
press cake, by the method described, and also
modified by adding acetic acid, after cooling,
to decompose saccharates of lime and precipi-
tated levulose, gave in each 9.6 per cent of
sucrose. A third portion of this sample was
rubbed to a cream with hot water and defecated
with subacetate of lead, then washed onto a
filter. The washing was continued with very
hot water to nearly 200 cc. of filtrate. The filtrate was cooled
and diluted to 200 cc. and polarized, giving a reading of 4.6.
The residue was washed into a sugar-flask and diluted to
100 cc. and filtered. The filtrate polarized 0.5. The sum
of 4.6×2+0.5 is 9.7, or nearly the same as in the other two
experiments, showing that 25 grams is approximately the
correct amount of average material to use instead of the
normal weight. Many experiments by the writer have given
similar results to those described.

Fig. 78.

100 cc.

ANALYSIS OF THE BAGASSE AND EXHAUSTED CHIPS (DIFFUSION).

150. Preparation of the Samples.—After securing the sample as described in **100**, it should be rapidly and thoroughly mixed and subsampled. The subsample should be quickly reduced to small pieces by chopping or shredding.

The preparation of the sample for the sucrose test is especially important. The pieces should be very small. The Java laboratories require this sample to be fine enough to pass through a 4-mm, sieve. De Haan [1] collaborated in the preparation of the Java instructions for bagasse analysis in which the above specification as to the sample is given. He, however, has stated [2] that the apparent influence of fineness is really largely due to incorrect sampling. This implies that the chemist unconsciously selects the larger pieces rather than an average of the sample. Norris [3] specifies 6 mm. as the diameter of the largest admissible piece of bagasse. In the opinion of the writer, attempts to reduce the material finer than Norris' specification may lead to errors through the drying of the sample, especially when the sucrose content is high. Norris [4] made numerous tests to ascertain the average loss of moisture during the preparation of the sample and found it to average 2 per cent when the chopper is covered and 4 per cent when uncovered. From these observations it is evident that the sample should be prepared as rapidly as is possible, and even then the sucrose numbers may be a little too high. There is often a compensating error that may offset this error, viz., slightly imperfect extraction of the sucrose in the digestion.

Slow preparation of the sample may result in a large error

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[1] Int. Sugar Journ., 1912, **14**, 43.
[2] Ibid., 5.
[3] Bul. 32, Haw. Sugar Planters' Expt. Sta., 32.
[4] Ibid., 8.

in the moisture test. This may be avoided by drying the bagasse as it comes from the mills, using the special oven described farther on.
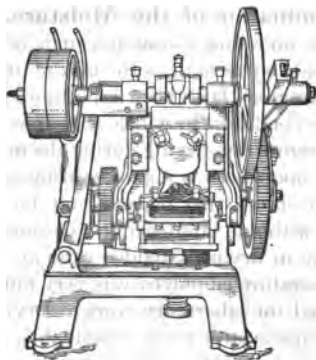
Fig. 79.
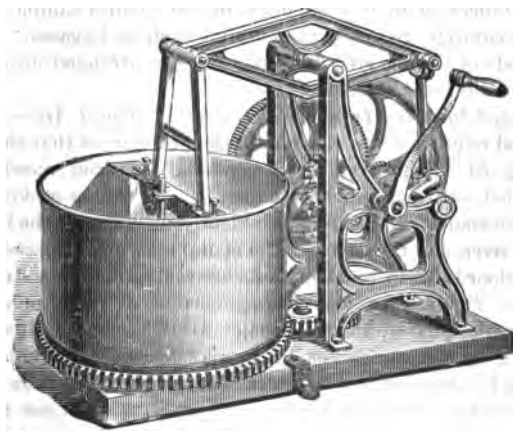
Fig. 80.

The Boot & Krantz chopper, Fig. 79, is very suitable for preparing the sample. The knife is adjustable to cut the bagasse to any desired fineness. The machine may be driven

by belt or by hand power. The Athol meat-chopper, size No. 405, Fig. 80, is an efficient machine for reducing bagasse. This machine has large capacity and may be covered during chopping.

151. Determination of the Moisture.—As has been indicated in the preceding paragraph, it is of importance to dry a large sample on account of the lack of uniform distribution of the moisture. It is also important that the sample be dried in the condition in which it is received from the mills, to avoid error from drying during the manipulations.

Experiments upon both a manufacturing scale and in the laboratory have shown that bagasse may be heated to high temperatures without appreciable decomposition. Such tests were made in drying shredded cane at Preston, Cuba, where the temperature employed was very much higher than is here suggested for laboratory work. Drying in vacuum-ovens at low temperatures is not dependable. Many writers recommend drying samples of 20 grams or even less. From the point of view of the test of the particular 20 grams there is no objection to this quantity, but so small a sample cannot accurately represent a material such as bagasse. The methods of drying given in this book are arranged in order of the writer's preference:

Method Involving Drying in a Current of Heated Air.—This method requires a special oven on the principle of that shown in Fig. 81. The oven is a cylindrical cast-iron vessel, C, provided with a removable cover, D. A rubber-gasket, I, and the clamps, E, insure an air-tight joint between the body of the oven and the cover. The clamp may not be necessary if the door is heavy and the joints are well ground. A steam-ejector, F, draws a very strong current of air through a heater, the pipe G, and the basket A. The air is heated by passing it over a steam-coil. It may receive a preliminary drying by drawing it over quick-lime, followed by filtration, but this does not appear to be necessary. A small size feed-water heater is an inexpensive and efficient heating device. If this heater is used with exhaust steam from the engines, the air should be drawn through the copper coil, the steam surrounding it, but with live steam the air should pass over the coil, The specific heat of air is low, hence the pipes

should be covered and a very large volume of it must be used.

A cylindrical bagasse-basket of very thin sheet brass, *A*, fits in the oven as is indicated.   Two or more baskets should be provided and tared if many samples are to be dried.   The bottom of the basket is of finely perforated brass plate, such as is used in centrifugals.   Sheet brass containing about 625 round holes per square inch is suitable for this purpose.   The top of the basket is open.   A narrow flange supports the basket and makes a joint with the iron castings.   The weight of the basket and bagasse and the pressure of the air are
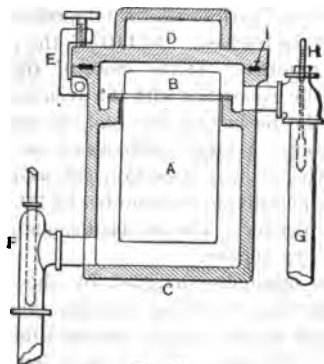
FIG. 81.

usually sufficient to insure a good joint, but if need be, a gasket of steam-packing may be used.   The thermometer, *H*, indicates the temperature of the air current.   If the oven forms one of a battery, a stop-valve should be provided in the pipe *G*.   A valve is also convenient in regulating the current of air.   If it is desired to leave the steam turned on the ejector, *F*, when opening the oven, it is necessary to provide an air-cock in the cover or elsewhere for use in breaking the vacuum.

This oven may be constructed of any convenient size. Those constructed for the writer will receive a basket 8 inches in diameter and 12 inches deep.   This basket will hold 1 kilogram of loose bagasse or 2 kilograms if lightly packed.   The

drying period is extended a few minutes by the packing. A basket of this size may be used with the 5-kilogram balance shown in Fig. 44.

The method of drying is as follows: Assuming efficient mill-work, reduce the sample to about 2 kilograms by subsampling; fill the tared basket with 2 kilograms of bagasse, packing it lightly as may be necessary. Insert the basket in the oven, replace the cover and turn sufficient high-pressure steam into the ejector to produce a very strong current of air. The air should be heated to any convenient temperature above 110° C. and preferably to 130° C. The air-pipe should be well covered.

The drying-period varies with the temperature of the air and the condition of the bagasse. At 110° C. the period is usually about ninety minutes. At the close of the drying-period, which after a little experience with the oven may be arbitrarily fixed, remove the basket by the bail, B, and place it in a desiccator to cool. A large earthenware jar will serve as a desiccator. After cooling, ascertain the weight in grams of the dry bagasse and divide this number by 20, to arrive at the per cent of dry matter. The per cent moisture is 100 minus the per cent of dry matter.

The oven as originally designed by the writer [1] is self-contained. The lower section contains the heating-coils, and in the upper are six bagasse drying-tubes of 200 grams capacity each. The oven illustrated is less expensive and is more accessible for repairs than the older model. It may easily be built in the plantation shops, largely from old material.

Drying in Packages.—The bagasse may be dried in packages covered with cheese-cloth or mosquito-netting. Several hours' heating at 110° C. are required to expel the moisture. Proceed as follows: Weigh about a yard of fine-mesh mosquito-netting, including a few pins, and determine the moisture in it. Wrap up about 2 kilograms of the bagasse, sampled as described above, in the netting and pin it together and quickly weigh it on a good scale. Dry the package of bagasse to constant weight in the steam

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dry ing-oven described farther on. In making the weighings
the package should be transferred directly to the scale with-
out awaiting the cooling of the material. While this intro-
duces a small error, this error is smaller than would otherwise
be the case through absorption of moisture from the air.
The calculation of the moisture is best shown by the follow-
ing example:

Weight of the mosquito-netting and pins. ⁓. . . . . . . 60 grams
Dry weight of the mosquito-netting and pins. . . . 56   "

Moisture. . . . .   4 grams
Weight of the package of bagasse. . . . . ·2060 grams
Dry weight of the package of bagasse. 1096   "

Moisture in the bagasse and netting. . . . . 964 grams
   "   " " netting   4   "

   "   " " bagasse. . . . . 960 grams

   2060 − 60 = 2000 = weight of the bagasse used.
   960 ÷ 2000 × 100 = 48.0 per cent of moisture in the bagasse.
The quantity of bagasse is so large in this method that an
error of 1 gram in the weight makes an error of only .05 in
the per cent.

   Experience has shown the dryings by this method to be
very complete, and that usually 24 hours are required
for the desiccation at 110° C.

   Manifestly a metal basket could be substituted for the
netting. A small quantity of bagasse-dust will sometimes
fall from the package, but its weight is too small to appre-
ciably affect the accuracy of the test.

   The oven shown in Fig. 82 is suitable for use in these
tests.

   Drying in Metal Trays.—Shallow metal trays may be used
as containers for the bagasse. A suitable size for use on the
sugar balance and holding 50 grams of bagasse is 4 inches by 8
inches by 1.25 inches deep. The drying progresses faster if
the bottom of the tray is of wire gauze or perforated sheet
brass. The temperature of the oven should be at least
110° C. and preferably 130° C.

Steam drying-oven.—The steam drying-oven is shown in Fig. 82. It is most conveniently constructed of 2-inch
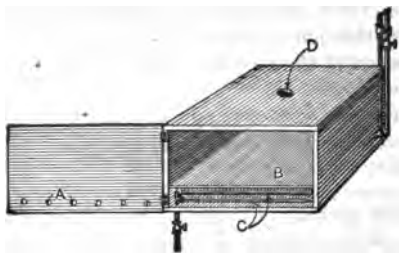
FIG. 82.

planks of well-seasoned lumber. Two steam manifolds, or coils, *C*, of iron pipe are used with live steam to heat the oven. Half-inch iron pipe is suitable for making the coils. The use of two coils, instead of one, facilitates regulating the temperature.

Holes in the door of the oven at *A* admit air, and the moist warm air escapes at *D*. A thermometer can readily be inserted in the oven by boring a hole in the wall near the shelf *B*. This shelf or tray *B* is made of a wire screen. The mesh should be large. The door and other parts should be protected from warping by the usual carpenter's expedients. There should be globe-valves on each of the inlet and tail-pipes, to each coil, to regulate the steam and the discharge of the condensation water.

An oven of this type is a very convenient part of a sugar-house laboratory equipment. It may not only be used for many moisture tests, but serves also in drying glass-ware, etc.

152. Determination of the Sucrose.—*Single-digestion Method.*—The following is the usual method of determining the percentage of sucrose in the bagasse: Weigh 50 grams of finely divided bagasse in a dry, tared flask of about 1000 cc. capacity and add 500 cc. water and 2 cc. of a 5% solution of sodium carbonate. The flask should be provided with a reflux condenser, for which purpose a small glass tube about 4 feet long will answer.

Heat the contents of the flask to gentle boiling and continue the heating during one hour. Cool and weigh the flask and contents. Drain off a portion of the solution, clarify it with dry subacetate of lead and polarize it, using a 400-mm. tube. The calculation of the sucrose in the solution is made by Schmitz's table, as described for use with dry lead, page 500. Or 100 cc. of the solution may be clarified with a few drops of the subacetate of lead solution, diluted to 110 cc. and the calculation of the per cent sucrose made as usual by Schmitz's table, page 506. With these very dilute solutions, the degree Brix need not be considered in the calculations.

The method of calculating the sucrose to terms of the bagasse is illustrated in the following example, in which the fiber or marc in the bagasse is assumed to be 45 per cent:

Weight of flask + bagasse + water	620	grams
" " "	110	"
" " bagasse + water	510	"
" " fiber in bagasse = 50×0.45 = ...	22.5	"
" " thin juice	487.5	"

Polarization of thin juice, Horne's method, page 179, using a 400 mm. tube = 4.4; 4.4÷2 (account of tube length) = 2.2 and the per cent sucrose corresponding, by Schmitz's table = 0.57. The per cent sucrose in the bagasse is therefore 487.5 × 0.0057 × 2 = 5.56.

A copper digester, Fig. 83, may conveniently be substituted for the flask. This should be about 4 inches diameter by 6 inches deep and be provided with a brass cover that may be clamped to it, making a tight joint. A brass tube attached to the cover serves as a condenser. A brass rod, carrying a small disk for mixing purposes, should pass through and extend above the tube. The rod should be moved up and down occasionally either by hand or mechanically. A Kodak developing-tank, fitted with a condensing-tube, may conveniently be used as a digester.

No water should be added to the bagasse after starting the digestion. The boiling should be very gentle or, preferably, the liquid should just reach the boiling-point. Rapid boiling, with consequent large return from the condenser, results in a dilution error.

Repeated Digestion Method.—In a suitable dish, preferably a porcelain casserole, cover 100 grams of finely divided bagasse with water and boil it during ten minutes. Drain off the liquid, pressing the bagasse with an iron spoon. Repeat this digestion with water and the decantation in all eight times. Press the residue of the bagasse in a powerful hydraulic or other press and unite the liquid expressed to those portions already drained off. Cool the liquid to the
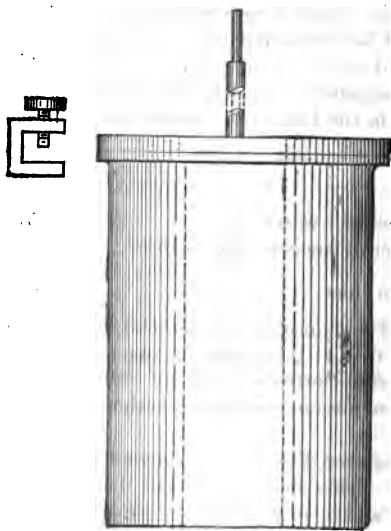
FIG. 83.

ordinary temperature and measure it, adding, if need be, a little water to bring it to an easily measurable volume. Clarify the solution by Horne's dry-lead method, page 179. The degree Brix of this very dilute solution may be neglected. Polarize the solution, preferably using a 600-mm. observation-tube, and calculate the sucrose with the aid of Schmitz's table on page 500. If the 600-mm. tube has been used the polariscope reading should be divided by 3. This per cent sucrose is that of the extract. Consider the cubic centimeters

of the extract to be grams and multiply this number by the per cent sucrose to ascertain the per cent sucrose in the bagasse. About 0.5 gram of carbonate of sodium should be added to the water used in making the first extraction.

Ceerligs [1] states that long digestion with boiling water dissolves a dextro-rotatory gum from the fiber of the bagasse and makes the polarization too high. De Haan extracted this gum and found that it is precipitated by the subacetate of lead.[2] Norris failed to find this dextro-rotatory substance in extracts from Hawaiian cane.[3]

Norris' Method.[4]—Dr. R. S. Norris, noting that one of the weak points in the sucrose test is the small polariscope reading, devised the follow- ing modification of the single- digestion method: A special digester, Fig. 84, *A*, is used. This is like the double cooker used in the kitchen for cereals, etc. A tamp, *C*, made of a heavy perforated metal disk and provided with a substantial handle, is fitted rather snugly into the inner vessel, *B*, and screes to press the bagasse and also as a

Fig. 84.

cover. The inner vessel should be 4.25 inches deep and 4.25 inches in diameter.
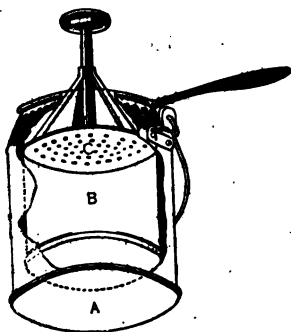
Weigh 100 grams of bagasse in the tared inner vessel. The tamp should be tared with the vessel. There should be no pieces of bagasse larger than 6 mm. in diameter. Add 500 cc. of hot water containing 5 cc. of a 5 per cent solution of carbonate of sodium. Place the vessel in the boiler and digest for one hour, pressing the bagasse and mixing the solution every fifteen minutes. The tamp should be fastened

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[1] Int. Sugar Journ., **11**, 156.

[2] Bul. 32, Haw. Sugar Planters' Expt. Sta., 12.

[3] Ibid., 18.

[4] Bul. 32, Haw. Planters' Expt. Sta., 24; Int. Sugar Journ., **12**, 641.

at the top of the inner vessel, when not in use, and serve as a cover. It should not be removed until after the completion of the digestion and weighing. At the conclusion of the digestion period, remove and wipe the inner vessel and set it aside to cool and weigh, or it may be cooled by placing it in cold water. The calculation of the per cent sucrose is made as in the single-digestion method, page 289.

Norris states that the shape and dimensions of the vessel apparently influence the results. The vessel should not be too deep. The dimensions given are those decided upon by Norris after many experiments.

153. Determination of the Fiber (Marc).—The fiber may be determined directly as in the cane, **110**, but preferably by the following indirect method. This method was adopted by the author after several thousand comparative tests in The Cuban-American Sugar Co.'s laboratories: The required data are obtained in the mill control.

Let S = the dry matter in the bagasse;

$\quad$ P = the per cent sucrose in the bagasse;

$\quad$ C = the coefficient of purity of the residual juice (*see* next paragraph);

$\quad$ x = per cent fiber (marc) in the bagasse,

then

$$x = S - 100P/C.$$

Steuerwald, of the Java Experiment Station, in an investigation of the various methods of fiber determination, arrived at the conclusion that the indirect method as above gives the most reliable results. He considers the claims of the water- and alcohol-extraction methods and concludes that the aqueous methods give high figures and the alcoholic extraction, even correcting for the separation of saccharetin from the fiber, gives low figures.

154. Purity of the Residual Juice.—The residual juice, *i.e.*, the juice remaining in the final bagasse, is considered by many chemists to correspond in purity to that of the juice extracted by the last mill of the train. The experience of the writer indicates that this is near the truth. However, since the bagasse receives its final and heaviest pressure between the last pair of rolls, the juice flowing from the last

roll probably more nearly approximates the true residual juice. The coefficient of purity of this juice is used in calculating the fiber. The analysis is made as for other juices.

155. Exhausted Diffusion-chips, Sucrose.—Express the thin juice from the well-drained chips by passing them through a laboratory-mill several times with heavy pressure, or press the chips in a powerful hydraulic press. The analysis is made as for other juices. Consider the polarization of this juice to be that of the exhausted chips.

The weight of the thin juice in well-drained chips corresponds very nearly with the weight of the fresh cane, and it is usual to so consider it. This weight may be estimated by the following method, in which the fiber is considered a constant, *i.e.*, all the fiber of the cane is found in the bagasse:

Let F = the fiber per cent cane;

$\quad F'$ = the fiber per cent exhausted chips;

$\quad 100$ = the weight of the cane;

$\quad x$ = the weight of thin juice in the chips,

then

$\quad F'(x+F') = 100F$ and $x = 100F/F' - F'$, the weight of thin juice per 100 cane.

Both the fresh and exhausted chips may be accurately sampled, hence the direct fiber determinations may be used in this calculation.

ANALYSIS OF FACTORY WASTES.

156. Analysis of Waste Water, Diffusion Process.
—The polarization of waste waters from the diffusion-battery
requires at least a 500-mm. observation-tube in order to
attain reasonable accuracy. The waters after filtration are
usually clear enough to polarize without the use of lead.
As few planters have polariscopes long enough for a 500-mm.
tube, a chemical method must generally be used.

Concentrate the sample to 5 per cent of its volume. Invert
the sucrose by means of hydrochloric acid in the propor-
tion of 5 cc. acid to 75 cc. of the concentrated sample (see
89). Nearly neutralize the acid, after inversion, with
sodium hydrate. Determine the glucose formed. Calcu-
late the glucose and multiply the per cent by .95; the
result will be the per cent sucrose plus the small quan-
tity of glucose naturally present in the waste water. This
quantity of glucose is too small to be taken account of, and
may be neglected. Use Meissl and Wein's table, page 189.

The presence of a considerable amount of sucrose in the
waste water is an evidence of gross neglect on the part of
the batterymen.

157. Analysis of Foam from Sirups, etc.—A
current of compressed air, or a little ether rapidly evaporated,
will quickly reduce the foam to a liquid. Remove the
ether by evaporation over warm water, at a safe distance
from fire, and proceed with the analysis by the methods
described, beginning **125**.

158. Analysis of the Boiler Feed-Water.—The feed-
water for the steam-boilers is largely derived from that
evaporated from the juice and sirup. The water from the
steam condensed in the calandria of the first vessel of the
multiple effect, the calandrias and coils of the vacuum-pans
and the coils and tubes of the various heaters forms a very
important source of water supply for the boilers. Sugar may

enter these waters through entrainment with the vapors from the juice and sirup and through defects that develop in the heating-surfaces.

Sugar causes the water to foam in the boilers and may lead to accidents. Further, though sugar may not be present in sufficient quantity to endanger the boilers through foaming, it is decomposed by the heat into products that are very detrimental to the tubes and shells of the boilers, causing pitting and overheating. The sugar is supposed to be first hydrolized, after which the dextrose and levulose decompose. The dextrose produces levulins, formic and acetic acids, and the levulose, humic and formic acids and insoluble humic compounds. Both the acids and the insoluble humic compounds are injurious to the boiler-plates. Humic compounds form only when the water contains ammonia or soda. Except for its action on levulose in forming humic compounds, ammonia does not appear to injure the plates.

Fats introduced into high-pressure boilers with the feed-water absorb the humic compounds and no longer float, but form thin threads which deposit in non-conducting layers.[1] Ammonia retards the chemical action which is most vigorous at the hottest parts of the boiler.

Sugar itself does not attack the boiler metal, but its decomposition products do, both chemically and physically. The chemical action has been explained. Some of the decomposition products deposit upon the heating surfaces with consequent overheating and damage to the plates.

The plates may also be attacked by the acidity in the water derived from sulphited juices. This may be prevented by the addition of soda to the water or preferably by reducing the acidity of the juices.

It is evident that a thorough control of the feed-water is the best safeguard against sugar. The moment sugar appears in the water this should be turned to the sewer and the boilers should be thoroughly blown down. The α-naphthol test as below should be used at very frequent intervals in testing the water and in tracing the sources of sugar in it. The odor

[1] Öster.-Ungar. Zeit. Zuckerind, 1912, **43**, 397; Int. Sugar Journ., 1912, **14**, 472.

of the steam is very pronounced when the water contains sugar.

Qualitative and Approximate Quantitative Tests for Traces of Sugar in Water.—The sucrose in the circulating water may be detected qualitatively by the α-naphthol method, and its quantity also estimated as follows: Add 5 drops of a 20 per cent alcoholic solution of α-naphthol to 2 cc. of the water in a test-tube, then by means of a pipette, reaching to the bottom of the tube, run in 10 cc. of concentrated sulphuric acid. In the presence of sucrose a violet zone appears at the line of demarkation of the two liquids and gradually spreads. In the presence of 0.1 per cent of sucrose, the color reaction is obscured by the darkening of the solution; with 0.01 per cent sucrose the color is that of very dark-red wine; with 0.001 per cent sucrose, the entire solution is colored.

The acid used in this test must be strictly chemically pure and the α-naphthol should be of very good quality. The solution of the reagent should be freshly prepared from time to time and should not be colored.

This test is extremely delicate. When the solution contains 1 part of sucrose in 10,000,000 parts of water a pale-lilac color is shown in the test, and with 0.2 per cent of sucrose, the sugar is charred by the acid.[1] A similar and possibly the original method was described by Molisch.[2] Also the following: Thymol instead of α-naphthol in the test yields a deep-red coloration, which on dilution with water gives at first a fine carmine, then a carmine flocculent precipitate.

159. Automatic Alarm for Sugar in the Boiler Feed-water.[3]—This alarm is based upon the change in density of the water in the presence of sugar. It is composed of two communicating tubes (communicating vessels) one within the other. The water is stagnant in the inner tube and flows through the outer at a constant level. A change of level in the inner tube causes a float to rise and close an electrical circuit and ring a bell. Since the water

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[1] Rapp and Besemfelder, Deutsche Zuckerind., 1892, 538.

[2] Monatsch. Chem., **6**, 198; Abstract in Jour. Chem. Soc. Abs., **50**, 923.

[3] Avertiseur Lavan, Ed. Gallois, Paris.

is of the same temperature in both tubes, the density is automatically corrected. The columns are 1.5 meters high, therefore a solution of 1.001 sp. gr. will lift the float 1 mm.

It is evident that the sensibility of the instrument may be increased by adjusting the contact. The instrument should be placed in a convenient location as free as possible of vibrations. A bell should be placed near the feed-water pump and another in the laboratory.

160. Cobaltous Nitrate Test for Sucrose.[1]—To about 15 cc. of sugar solution add 5 cc. of a 5 per cent solution of cobaltous nitrate. After thoroughly mixing the two solutions, add 2 cc. of a 50 per cent solution of sodium hydrate. Pure sucrose gives by this treatment an amethyst-violet color which is permanent. Pure dextrose gives a turquoise-blue color which soon passes into a light green. When the two sugars are mixed the coloration produced by sucrose is the predominant one, and 1 part sucrose in 9 parts dextrose can be distinguished. If the sucrose be mixed with impurities, such as gum-arabic or dextrin, treat with alcohol or subacetate of lead before applying the test.

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[1] Agricultural Analysis, H. W. Wiley, Vol. III, p. 189.

ANALYSIS OF MOLASSES CATTLE-FOOD
(MOLASCUIT).[1]

161. Determination of the Moisture.—Dry 5 grams of the food in a flat dish, at the temperature of boiling water, for 10 hours; cool in a desiccator and weigh. Repeat the drying 1 hour and weigh as before. If there has been only a slight change of weight, note the total loss as the weight of water driven off. This weight multiplied by 20 is the percentage of moisture in the sample.

The lead bottle-caps, used by dealers in chemical supplies, form very convenient dishes for moisture determinations. They are very inexpensive and may be obtained of many different sizes. After use they are to be thrown away.

162. Determination of the Ash.—Incinerate 2 grams of the material as described in **121.**

163. Ether Extract.—Extract 2 to 3 grams of the food, dried as described in paragraph **161,** with anhydrous alcohol-free ether. The extraction is most conveniently made in a percolator, using Knorr's modification of Soxhlet's apparatus shown in Fig. 85. The tube D is connected by a cork with a small tared flask containing ether. The outer tube is connected with a reflux condenser and the tube A or percolator is prevented from closing the tube D by a spiral C of copper wire. A syphontube S is sealed into the lower part of the small percolator
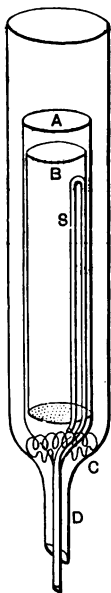
Fig. 85.

A, and lies close to the wall. The lower part of the tube
B is closed with a perforated disk of platinum.

In using the apparatus the weighed material is placed in
B, with a light plug of ether-extracted cotton on top of it, and
the percolator is connected with the reflux condenser and
the ether-flask; this latter is placed on a water-bath and
the water is heated with an electric lamp or by steam.
In using a flame there is danger of igniting the ether. The
ether vapors ascend to the condenser where they are con-
densed and the ether drips into the tube *B*. The tube *B*
fills with ether to the top of the syphon and is then carried
back by this into the flask.   This extraction should be
continued for 16 hours. The ether is removed from the
flask by evaporation and the extract is dried in a water-
oven to constant weight. The percentage that the residue
is of the original material is reported as ether extract.
If preferred the extract may be indirectly ascertained
by determining the loss in weight of the material in the
tube *B*.

164. Crude Protein.—Determine the nitrogen as de-
scribed in **122** and multiply the percentage by 6.25 to ascertain
the per cent of crude protein.

165. Crude Fiber.—Extract 2 grams of the food with
ether and to the residue, in a 500-cc. flask, add 200 cc. boiling
1.25-per cent sulphuric acid.   Connect the flask with a
reflux condenser and boil the liquid for thirty minutes. A
blast of air conducted into the flask may serve to reduce the
frothing of the liquid. Filter and wash the residue with
boiling water until the washings are no longer acid. Rinse
the material back into the same flask with 200 cc. of
boiling 1.25-per cent solution of sodium hydroxide and boil
for thirty minutes as before.   The sodium hydroxide should
be free or nearly so from sodium carbonate. Collect the
residue in a tared Gooch crucible and wash it with boiling
water until the washings are neutral. Dry the residue at
110° C. and weigh it; incinerate it completely and again
weigh. The loss of weight is calculated as crude fiber.

The filter used in the first filtration may be of linen,
asbestos, or glass wool. The acid and alkali solutions should
be standardized by titration.

166. Sucrose and Glucose.—The sucrose and glucose are determined by the chemical methods given in page 187. The solution for analysis is prepared by extracting a small weighed portion of the cattle-food, 10 grams for example, with successive portions of boiling water on a filter-paper. The filtrate is cooled and diluted to a suitable volume, 500 cc. The preliminary tests in the glucose work will indicate the proper dilution.

167. Notes on Cattle-food Analysis.—The moisture and the sugar tests are usually required by the factory in the control of the manufacture. The material is usually in excellent condition for the analysis, without further preparation.

DEFINITIONS OF EXPRESSIONS USED IN SUGAR WORK AND THEIR APPLICATIONS.

168. Normal Juice. Undiluted Juice. Absolute Juice.—The normal or undiluted juice was originally assumed to be the juice as it actually exists in the cane. These expressions are now applied to the juice extracted by dry-milling, *i.e.*, milling without saturation of the bagasse. The expression "undiluted juice" is perhaps preferable to "normal juice," but long usage has established the latter.

The cane is known to contain water that is free of sugar (**109**). This is termed "colloidal water." If a piece of cane be passed between the rolls of a mill a part of this water exudes and drips from the end of the stalk. In view of the presence of this water it becomes difficult to define the juice as it exists in the cane, in the light of factory requirements. For calculations based upon the whole or normal juice of the cane, it may be well to consider this the water-soluble constituents—juice solids dissolved in all the water contained in the cane. This may be termed the "absolute juice." This would assume that all the cells may be broken down and the solids be distributed in their liquid content. The cells are never all ruptured in milling, therefore the juice extracted in dry milling can only approximate the "absolute" juice. This fact has an important bearing upon the inferential methods of calculating the weight of the cane, saturation-water, juice content, etc. The customary use of "normal juice" as explained above is that employed in this book. The analysis of the normal juice is calculated from the density of the crusher or mixed-crusher and first-mill juice, and the purity of the mixed or diluted juice (**169**). A factor is calculated from the density of the crusher-juice and that of the mixed juices obtained in dry-milling. This factor is applied to the crusher-juice density to ascertain that of the normal juice. Example: Crusher-juice Brix, 20°; mixed juice

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Brix, 19.7; factor or ratio = 19.7 ÷ 20 = 0.985. *See* also page 323.

169. Mixed Juice. Diluted Juice.—These expressions are used to indicate the juice extracted by all the mills as it is finally mixed and sent to the defecation-station. This juice is usually diluted with the saturation water.

170. Bagasse. Megasse.—This is the woody residue left after expressing the juice from the cane. The word "megasse" is used in the English colonies.

171. Residual Juice.—The bagasse may be regarded as a sponge that absorbs and retains a part of the juice. The juice so retained, the residue of that in the cane, is the "residual" juice. The true residual juice can only be approximated and in the analysis only the coefficient of purity of an assumed residual juice is determined. This number is used in calculating the percentage of fiber or marc in the bagasse and cane. In practice the juice flowing from the last mill of the train or the last roll of that mill is considered to have the same coefficient of purity as the true residual juice. The writer uses the juice from the discharge-roll of the last mill in this test.

172. Fiber or Marc.—This is the water-insoluble matter of the cane. The true fiber or cellulose is not determined in the factory control.

173. Sirup.—The sirup is the concentrated juice of the cane from which no sugar has been extracted. This is the "meladura" of the Spanish-American factories. The word "sirup" has an opposite meaning in sugar refineries where it is applied to solutions from which sugar has been removed.

174. Massecuite.—The massecuite is the concentrated sirup or molasses in which the sugar has been crystallized or the material has been concentrated to a point where it will crystallize. Massecuites are designated by names or numbers indicating their purity or the number of crops of crystals of sugar that are to be removed.

175. Molasses.—When a massecuite is spun in a centrifugal machine the sugar crystals are separated from the mother liquor. This liquid is now termed "molasses," and is designated by names and numbers corresponding with

the massecuites. The "final" or true molasses is the liquid
residue from which no more sugar can be removed, either on
account of factory equipment or for commercial reasons.
This is termed "barrel-sirup" in the refineries.

176. Circulating Water.—This is the water used in
condensing the vapors in the evaporation of the juice and
sirup. After leaving the condensers, this water, together
with that derived from the vapors, is usually passed over a
cooling-tower to reduce its temperature, and it is returned
to the condenser, thus circulating through this apparatus.
This water is often termed "cooling-tower water."

177. Sweet-water.—The vapors condensed in the
calandrias of the evaporator often contained sugar, carried
into it by entrainment, with the older types of apparatus.
The water resulting from these vapors was called "sweet-
water," and still receives this name, though with efficient
apparatus it contains no sugar. In refinery practice any very
dilute sugar solution is termed "sweet-water."

178. Entrainment.—When sugar is carried off with the
vapors from the evaporators and vacuum-pans, this is called
"entrainment."

179. Coefficient of Purity.—The coefficient of purity as
usually applied is the percentage of apparent sucrose in the ap-
parent solids (Brix) of the material. This coefficient is calcu-
lated by dividing the per cent sucrose, as ascertained by direct
polarization, by the degree Brix of the substance and multi-
plying the quotient by 100. The number calculated in this
way is not the true coefficient of purity but only the *ap-
parent coefficient.* The *true coefficient* of purity is calculated
in the same manner, except that the percentage of solid
matter as ascertained by actually drying the material and the
sucrose as determined by the Clerget or double-polarization
method are used.

The general usage in the sugar industry is to apply the
term "coefficient of purity" to the number when calculated
from the apparent degree Brix and the sucrose by direct
polarization. It is well known that this coefficient so calcu-
lated is an approximate number, but for comparative purposes
it is of great value in sugar manufacture and will doubtless
always be so used. Frequently approximate data of the purity

of a product are required for immediate use, and as the factory superintendent cannot wait for a tedious determination of solids and an even more tedious double polarization, he uses the apparent coefficient, bearing in mind its shortcomings.

Since allowances must be made, it is advisable that the analyses be always conducted under very similar conditions, that due weight may be given the coefficient.

On the other hand, the *true coefficient of purity* is only used in special researches and in making comparisons among the various products at different stages of the manufacture or in comparing the work of two or more factories. In using this coefficient the word "*true*" should never be omitted, as is often the case, rendering what would otherwise be valuable data almost useless.

The expressions "quotient of purity," "degree of purity," "exponent of purity," and often simply "the quotient," and the "exponent" are used in referring to this coefficient.

With modern methods of sugar-house work, "boiling in" molasses and using crystallization in motion, the apparent coefficient is very frequently required and is of very great value.

180. Glucose Coefficient, Glucose per 100 Sucrose, Glucose Ratio.—This number is calculated as follows:

$$\frac{\text{Per cent glucose} \times 100}{\text{Per cent sucrose}} = \text{glucose coefficient}.$$

This coefficient is useful in detecting inversion of sucrose in the manufacture. Provided no sucrose has been separated from the material and no glucose has been removed or destroyed, an increase in the glucose coefficient indicates inversion.

It is possible but hardly probable that by the destruction of both sucrose and glucose the relations between the two sugars might remain the same and yet inversion have occurred.

181. Saline Coefficient.—The saline coefficient is the quantity of sucrose per unit of ash.

Calculation:

$$\frac{\text{Per cent sucrose}}{\text{Per cent ash}} = \text{saline coefficient}.$$

182. Apparent Dilution (Diffusion Process).—The apparent dilution is the amount of water that has been added to the normal juice to increase its volume to that of the diffusion-juice. This assumes a certain juice-content in the cane.

183. Actual Dilution.—This expression is used both in milling and diffusion work and is the percentage of water added to the normal juice to reduce its density to that of the diluted juice. Hence it represents the actual evaporation, in percentage terms of the normal juice, to remove the water of dilution. This number is preferably reduced to terms of the weight of the cane.

184. Notes on Coefficients.—The remarks in paragraph 179 in regard to apparent and true coefficients apply to all coefficients derived from the percentage of sucrose, the degree Brix, or the solids by drying. According to usage, except where otherwise stated, the apparent coefficients are meant.

185. Available Sugar.—Several formulæ are in use for the calculation of available sugar or the sugar it is assumed that a factory should be able to obtain with juices of a given analysis. Manifestly there are several conditions that control the proportion of sugar that may be considered available in the mill-juice, viz.: the efficiency of the machinery, the quality of the juice, and the skill of the factory superintendent. In considering the quality of the juice, the nature of its impurities, as well as its richness, should be taken into account. A cane grown on certain soils may take up more melassigenic substances than one of the same richness and equal apparent purity from another soil, and consequently the proportion of actually available sugar would be quite different, whereas a formula would indicate the canes to be equal.

Available sugar-numbers are but rough approximations except when the elements of the factory equipment and efficiency are taken into consideration. The yield or recovery of sugar varies with the coefficient of purity of the juice and the losses in manufacture, hence a formula for available sugar must take these elements into account.

The practical application of available sugar calculations.

except in estimating return from new investment, is in comparing the present work of a factory with that of some previous period or with that of a factory similarly located as regards soil and climate. Such calculations are of value in the control of several establishments operated under a central organization. In this event it is desirable to know (1) without stock-taking, how nearly a factory is approaching its previously demonstrated efficiency; (2) how much sugar is in process to determine whether the factory is becoming congested and requires either a reduced grinding-rate, a modification of the process, or closer supervision of the personnel; (3) how much sugar is in process for commercial or accounting reasons and (4) whether it is more profitable to reduce the rate of grinding or sacrifice somewhat in juice extraction.

Available sugar estimates also become necessary when cane is purchased on a basis of its analysis.

The earlier formulæ for available sugar were evidently based upon refining experience and possibly that of beet-sugar factories. The conditions in both of these branches of the industry are very unlike those of the cane-sugar factory and will not apply very fully in the calculation of the production of sugar from cane.

The following formula by Winter and Carp was published by Prinsen-Geerligs [1] and is based upon experience in Java, which represents very favorable tropical conditions:

x = available sucrose per cent cane;
S = per cent sucrose in the juice in terms of the weight of the cane;
C = coefficient of purity of the juice.

$$\therefore\ x = S \times \left(1.4 - \frac{40}{C}\right).$$

To calculate the available sucrose to terms of the available sugar, divide the value of x by the polarization of the sugar and multiply the quotient by 100.

The formula of Winter-Carp-Geerligs has been found of great value in the writer's tropical experience. When used

[1] International Sugar Journal, **6**, 439.

in connection with an efficiency number (**187**) the yield or recovery of sugar may be estimated with very considerable accuracy from the weight of the cane, the mill extraction and the analysis of the juice. It is perhaps needless to state that the analytical data must be based upon accurate sampling. Should the sampling be inaccurate these calculations will call attention to the inaccuracy.

The second part of the formula, $100(1.4 - 40/C)$, gives the "sucrose retention" or "recovery" number (**186**), and this number divided by 0.96 gives the recovery in 96° sugar. A table of the values of $100(1.4 - 40/C)$, and this value divided by 0.96 is given on page 515.

The following example illustrates the use of this formula and the efficiency number (**187**) in calculating the available 96° sugar:

Sucrose in the cane, per cent 14.1
Extraction, sucrose per cent sucrose in the cane 93.49
Coefficient of purity of the juice 84.1
Boiling-house efficiency number 99

Sucrose extracted per cent cane = $14.1 \times .9349 = 13.18$; referring to the second part of the table, page 515, the recovery number corresponding to 84.1 coefficient of purity is 96.29 and $13.18 \times .9629 = 12.69$, the available 96° sugar per cent cane if the efficiency number were 100. Applying the actual efficiency number, 99, we have $12.69 \times .99 = 12.56$, the available 96° sugar.

The following "run" and "to date" yields of a large Cuban factory indicate the reliability of this method for available sugar:

96° CENTRIFUGAL SUGAR PER CENT CANE

For the Run		To Date	
Actual Yield.	Calculated.	Actual Yield.	Calculated.
9.96	10.13		
10.72	10.58	10.35	10.28
11.50	11.38	10.70	10.68
11.85	11.84	10.98	10.98
12.44	12.33	11.31	11.39

It should be remembered that "run" figures are more liable to fluctuations than "to date," as they may be affected by the errors of estimate of two runs. It should be stated that this factory was operated beyond its normal capacity, thus necessitating slight changes in its efficiency number from time to time. This affects the estimate of the available sugar as the "to date" efficiency number, for the previous run is used in the calculation. Also in the first run the average number for the previous crop is used.

186. Sucrose Retention or Recovery.—This number is the percentage of the sucrose in the extracted juice that is retained or recovered in the commercial sugar. In the following example of a sucrose balance, 92.32 is the retention number:

Sucrose in the extracted juice, per cent...		100
Sucrose in the sugar per cent sucrose in the extracted juice.................	92.32	
Sucrose in the molasses per cent sucrose in the extracted juice...............	6.58	
Sucrose in the press-cake per cent sucrose in the extracted juice...............	.44	
Sucrose in the undetermined per cent sucrose in the extracted juice..........	.66	100

187. Boiling-House Efficiency Number. — Many factories use efficiency numbers to show how nearly a theoretical yield of sugar is obtained. This number is usually the percentage relation between the actual retention or recovery number (**186**) and the number based upon an available sugar formula. A part of the Winter-Carp-Geerligs formula, $100(1.4-40/C)$, is used by the author in calculating the Efficiency Number of The Cuban-American Sugar Co.'s factories. This calculation is best illustrated by an example: Let the coefficient of purity of the raw juice be 86.0 and actual retention number be 92.32, as in the previous paragraph, then $100(1.4-40/86)=93.49$; $92.32 \div 93.49 \times 100=98.7$, the efficiency number. A table is given on page 514 from which the value of $100(1.4-40/\text{Purity})$ may be ascertained by inspection.

The efficiency number is of value in calculating sugar actually available, as it takes into account the losses in manufacture in the particular factory as compared with those in the factory on whose work the available sugar formula is based.   This number may exceed 100 in some cases.

CHEMICAL CONTROL OF SUGAR-HOUSE WORK.

188. Introductory.—The chemical control of the factory is intended primarily to guide the manufacture along lines of best practice and to assist in detecting and reducing losses of sugar.

The chemist in the factory corresponds with the auditor in the accounting department. He charges the superintendent with the sucrose entering the factory in the raw material and credits him with that leaving it in the products, by-products, and losses. It is his duty to trace the travel of the sucrose and locate losses.

The control of the milling considers the cane from its delivery to the crusher to the delivery of the juice to the boiling-house and the bagasse to the fires. It is quite as important to ascertain the loss in the bagasse as to report the extraction of juice and sucrose to the engineer. The engineer should not so much consider the proportion of sugar extracted as that lost. The effort should always be the reduction of losses. It requires the assistance of the chemist in locating the causes of these losses.

The crystallization of the sugar should receive constant attention. The purity coefficients of the massecuites should be maintained at certain numbers, that the pan-work may progress systematically and efficiently and that no unnecessary work be thrown upon the crystallizers. This facilitates the reservation of a large part of the crystallizer capacity for the low-purity massecuites. The crystallizers must be controlled to meet the best conditions of equipment and manufacture. Molasses is often sold on a basis of its test, and in this event the control of the massecuites becomes of additional importance.

The quality of the sugar must be controlled to maintain it upon a basis of the most profitable analysis. The moisture content must be kept within certain limits to protect the sugar from deterioration in storage.

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The chemist is also the statistician of the factory. He reports the quantity and quality of the raw materials, the analysis of the materials in process of manufacture and of the products and by-products. The chemist prepares statistics that have a bearing upon the control and economy of the manufacture and the business of the establishment.

Research work in connection with the improvements in the equipment or processes is often called for and this often necessitates both technical and chemical training on the part of the chemist.

The laboratory should be a part of the training-school for future superintendents. The chemist becomes acquainted with all the methods, problems and difficulties of the manufacture. His control of the work should familiarize him with the details of the processes. The chemist's training unfortunately lacks the opportunity for practice in directing and controlling labor. This must come to him before he can leave the school of the superintendent. He must also acquire a good working knowledge of pan-boiling.

A lesson that must be learned early in factory control is that samples must be representative of the materials and their integrity must be unquestionable. Apparatus and methods must be adapted to the work in hand. Where the highest feasible accuracy is required, as in the testing of the raw materials and the products, no detail should be omitted or labor spared that may lead to dependable results.

The following is an outline of the factory control. This may be greatly extended by introducing "true" numbers instead of apparent for sucrose, etc., but this does not usually appear necessary in routine control:

The weight of the cane is reported to the chemist and from this number and the weight and analysis of the raw juice extracted he calculates the mill-control numbers for the engineer and the weight of sucrose chargeable to the superintendent. He must later account for this sucrose in the products, by-products and losses. The mill control depends very largely upon the analysis of the bagasse, and in some cases, entirely upon this analysis.

The raw juice is the starting-point in the control of the manufacture. Its weight and analysis are also elements of

the mill control. The weight of the sucrose extracted in the
juice plus that remaining in the bagasse is the basis of the
determination of the percentage and weight of sucrose enter-
ing in the cane and for the calculation of the sucrose extrac-
tion.

The analysis of the sirup or concentrated cane-juice, the
"meladura," of the Spanish-American factories, is the con-
trol of the purification of the juice and its evaporation, and
is a guide in the sugar-boiling. To obtain satisfactory results
in pan-boiling and to bring this work to as nearly a scientific
basis as is possible, the analysis of the massecuites and
molasses is necessary. Massecuites are now usually boiled
to specified purities by the injection of molasses. Careful
control of this work is essential to a systematic grading of
the materials for the most profitable extraction of the sugar,
considering the limitations of the factory. Control tests
are also often required in the conduct of the crystallizers.
The products, sugar and molasses, are controlled both as
a check upon the manufacture and to meet market con-
ditions.

The filter-press cake is usually the only by-product whose
weight may be ascertained. Its analysis is usually limited
to the determination of the sucrose, though occasionally
the solids must be determined for controlling the efficiency
of the pressing and the quantity of water used in "sweetening
off," or in reducing the cake for refiltration.

A loss of sucrose may occur through entrainment in the
multiple-effects and vacuum-pans. A knowledge of the
temperatures of the condensing and condenser-waters is
required in estimating this loss (313).

In the opinion of the author, many of the so-called mechan-
ical losses in manufacture are not actual losses, but are
apparently so through inaccuracies inherent in certain of
the processes of analysis.

Except in very large factories, which can afford a sufficient
force of chemists, a complete chemical control is not prac-
ticable. The chemist must judge from the equipment of
the factory what work may be omitted without decreasing
the efficiency of the sugar-house. He must under all condi-
tions determine when he may properly, to some degree,

sacrifice accuracy for the sake of promptly obtaining approximate figures for immediate use.

It is just as important, in a large factory, that the chemical control be complete and the laboratory records well arranged as that the accounts of the various departments be full and accurate.

<center>WEIGHTS AND MEASURES.</center>

189. General Considerations in regard to Weights and Measures.—It is quite essential that all weights and measures should be of the same system or be reduced to the same system. This remark applies especially in Spanish America, where it is not unusual to find English and Spanish units used indescriminately.

The system of weights and measures adopted should be applied as accurately as possible. A checking-system should be devised to meet the conditions of the factory and in so far as may be possible eliminate errors in the calculations.

190. Cane Weights.—There are few factories that do not weigh their cane, especially among those making even a pretense of a chemical control. Cane weights, however, are not essential to the control of the boiling-house, and in a measure may be dispensed with in mill control. In this event the mill control depends entirely upon the analysis of the bagasse and the juices.

It is the general custom to use the Spanish pound in weighing cane in Cuba. These weights are reported in arrobas of 25 pounds, Sp. The ton (*tonelada*) contains 2000 pounds (*libras*) Sp. There is some confusion on the part of scale-makers as to the equivalence of the Spanish pound, though the leading scales are properly graduated. A decree of a Spanish Captain General in Havana gave the equivalence as 100 Spanish pounds = 46.0096 kilograms, therefore 100 Spanish pounds = 101.4338 avoirdupois pounds. Scale-beams graduated in Spanish pounds use the word "libra."

It is the custom in Cuba and in most factories to reweigh the cane on a central scale immediately before grinding it. This weight should be used in the control.

It may occur through conditions beyond the control of the chemist that the weight of the cane must be estimated by an inferential method. Small factories, and even the large ones of Louisiana, often store the cane in large piles, liquidating these as often as is practicable. In certain localities the cane is flumed or floated to the mills in water. These special conditions call for an inferential method. Such methods should only be used in estimating the cane for statistical purposes and not in the serious control of the factory. Inferential methods require a knowledge of some constituent of the cane that may be traced through the milling process, e.g., the fiber, solids, or sucrose. The following example, from the records of a factory, illustrates an inferential method:

Assume a factor which applied to the analysis of the crusher juice will give approximately the percentage of sucrose in the cane. This factor varies with the variety of cane, the fiber content and the milling conditions. It is smaller with light than heavy crushing. The factor approximates 0.85 with heavy crushing. Deerr [1] found factors varying from a minimum of 0.81 to a maximum of 0.848 and an average of 0.825. According to Pellet [2] the factor in Egypt is usually from 0.83 to 0.84 and may be as low as 0.82 to 0.80. The writer has determined factors as low as 0.80 in Cuba, the low numbers being probably the result of the very large duty required of the crusher:

Factor assumed............................	0.80
Polarization of the crusher juice............	18.45
Tons sucrose extracted in the mixed juice...	305.7
Fiber in the cane (direct test)..............	11.3
Fiber in the bagasse (direct test)...........	48.9
Bagasse per cent cane $= 11.3 \times 100 \div 48.9 =$	23.11
Sucrose in the bagasse, per cent............	4.5
Sucrose in the cane, per cent $= 18.45 \times 0.80 =$	14.76
Sucrose in the bagasse per cent cane $= 23.11$	
$\times 0.045 = $............................	1.04

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[1] Int. Sugar Journ., 1911, 13, 15.

[2] Int. Sugar Journ., 1912, 14, 587.

Weight of cane = sucrose extracted ÷ sucrose per cent in cane — loss in bagasse = 305.7 ÷ (14.76 − 1.04) = 2228 tons. The weight reported from the central scales was 2209 tons, showing the factor to be approximately 0.80. In this example, taken from the records of a well-controlled factory, the fiber in the cane was actually determined by the indirect method. Where an inferential method must be used a direct fiber determination must be made, thus adding to the uncertainty of the method. In this method, but three elements are accurately determined, viz., the polarization of the crusher juice, the sucrose extracted by the mills and the analysis of the bagasse.

191. Weight of the Juice.—Several automatic scales for weighing juice are on the market. These claim to be accurate, but the writer has no experience with them. Tank scales, arranged in pairs and not automatic, give accurate figures. The tanks have conical bottoms to facilitate washing. Counters, printing counterpoises and other control devices are used with these scales. A factory grinding about 2000 tons of cane per day requires two tanks, each holding about five tons of juice.

192. Measurement of the Juice and Calculation of Its Weight.—The measurement of the juice gives comparable figures when it is conducted under favorable conditions.

The measurement may be made with a good degree of accuracy in factories using separate liming-tanks. At least three tanks are required and these should be connected with a much deeper tank, serving as a pump-tank. The pump-tank must be deep enough to admit of complete drainage of the liming-tanks. The tank-valves should be well ground to prevent juice from passing from a full to an empty tank. All of the tanks should have conical bottoms and spray-pipes for washing. An overflow-pipe should connect each tank and with a trunk line leading back to the mills. A "T," inside the tank, should connect by the side branch with the overflow-pipe. The upper outlet of the "T" should be extended well above the foam on the surface of the juice and the lower outlet a few inches below the surface, by nipples. The object of this arrangement is the provision of

a free overflow for the juice, without interference by foam. A 3-inch "T" is a suitable size.

The measuring-tanks should be calibrated with water under service conditions. Corrections must be applied to the measured volume for temperature, milk of lime added and for air entrained with the juice. The allowance for air should be determined experimentally. It varies with milling and pumping conditions. A tank should be filled to the overflow with juice and its temperature be noted. After a few hours the temperature and shrinkage of the juice should be noted. A factor should then be figured from these data, making allowance for change due to temperature. It is advisable to add formaldehyde to the juice to insure its preservation and to make the period of rest as long as practicable. Occasionally factories warm the juice moderately on its way to the liming-tanks. This reduces the error due to entrainment of air. The method of calculating the weight of the juice from its volume is given on page 347.

Many factories are compelled to measure the juice in the defecators. Such measurement is very unsatisfactory. A block of wood should be arranged to indicate the point to which the vessel is to be filled. Correction must be made for the milk of lime use and for temperature. It is customary to heat the juice the moment the heating surface is covered, reaching the "cracking" temperature about the moment the defecator is full. This expels the air and gases which carry a part of the precipitated impurities to the surface with them. This scum adds to the difficulty of making an accurate measurement. The calculations are made as given on page 347.

It is quite a usual practice in Louisiana, where a single tank is often used for the defecation and clarification, to allow the skimmings to remain in the troughs some time in order to separate the clear juice entrained with them; this clear juice is finally drawn back into the defecator and reclarified, no account being taken of its volume. The average volume of such juice should be determined, and deducted in calculating the net volume. The chemist will soon learn that it is only by extreme care and vigilance that he can succeed under these conditions in obtaining

reasonably accurate measurements and samples. In addition to the sources of error indicated, there is another due to the necessity of depending upon the workmen to keep the count of the number of defecators of juice.

Automatic counters and recording tank-gauges may be used in controlling the measuring-tanks. The recording gauge serves as a check upon the filling and emptying of the tanks.

When large tanks are used as in these processes it is well to provide a printed sheet for each liming-tank, on which the workman should note the time when he begins filling and when he finishes filling a tank and the volume of milk of lime used. With these data the chemist can ascertain the number of tanks filled with juice, whether the workman's record is correct, and also the correction to be applied on account of the volume of the milk of lime. The temperature of the juice should also be occasionally noted.

Automatic Measurement of the Juice.—The juice may readily be strained through a perforated brass plate, containing 324 round holes to the square inch, by means of the link-belt strainers and trash-elevators, now so generally used. This thorough straining facilitates the measurement of the juice, though it will not usually admit of the use of meters.

The automatic or semi-automatic measurement of the cold juice, as it flows from the mills, eliminates many of the sources of error indicated in the preceding paragraph. Apparatus for such measurement of the juice is but little used.

One of the most reliable methods of measurement is by means of a combination of tanks and an automatic recording apparatus such as that described farther on and illustrated in Fig. 86. This method requires two tanks with an overflow from one to the other, and very large discharge-pipes and preferably two automatic registers. The discharge- and inlet valves may be changed either by hand or automatically. When changed automatically the valves are operated by floats or by mechanism put in action by means of electrical devices.

Measurement of the juice in diffusion work.—The diffusion process requires the measurement of the juice from each cell. A water-gauge should be attached to the measuring-

tank. A colored float in the gauge-tube facilitates noting the exact measurement. This is more reliable than the measurement by means of an ordinary float. Several methods have been devised for the accurate measurement of the diffusion-juice, but more especially with a view to preventing the batteryman from drawing too much or too little juice.
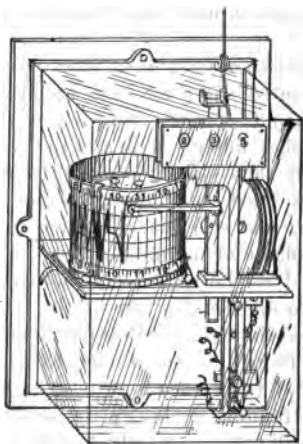
FIG. 86.

The method suggested above, together with the automatic register described below, is one of the most convenient. The workmen take pride in a record-sheet free of errors.

The automatic registration of the amount of juice is of very great importance. The weight of the juice derived from its volume, or by direct weighing, is the basis of nearly all calculations of sugar-house losses. An accurate knowledge of the volume of the juice is of especial value in locating errors and in preventing undue and irregular dilution. Irregularities of dilution not only occasion losses of sugar, but increase the cost of fuel. The automatic apparatus of Horsin-Déon, illustrated in Fig. 86, registers the amount of juice drawn, and the rate of drawing and all delays. It consists essentially of a recording cylinder revolved by clockwork. A float in the measuring-tank is connected by means of a wire or chain with a drum, which revolves

when the float rises or falls; on the shaft of the drum is a pinion, which in revolving engages a rack; this latter in turn is attached to a small arm, which carries a pencil. When the juice enters the tank the float lifts, revolves the drum, and by reason of the rack and pinion the pencil traces a line on the paper-covered cylinder. The paper is divided into 12 parts, corresponding to the hours of two watches;[1] each part is subdivided into 5-minute spaces. The cylinder revolves once every twelve hours. It is obvious that this instrument may also be used in mill-work, in which case it should be attached to a suitable measuring-tank.

The Weight of the Juice.—In calculating the weight of the juice from its volume and density, the volume should be corrected for expansion to correspond with conditions of the graduation of the hydrometer. In using the Brix spindles, which are graduated to give the density of the solution at $17\frac{1}{2}°$ C. as compared with water at this temperature, the volume of the juice should be corrected to $17\frac{1}{2}°$ C. The weight of a cubic foot of water at the normal temperature, $17\frac{1}{2}°$ C., is 62.2795 lbs., and that of the United States gallon, of which there are 7.4805 per cubic foot, is 8.3255 lbs. These numbers may be used in calculating the weight of the juice under the above conditions. A table is given to facilitate these calculations (page 495).

If the hydrometers are graduated to the temperature standard adopted by the International Chemical Congress, the volume of the juice should be corrected to 4° C. The weight of a cubic foot of water at 4° C. is 62.3565 lbs.

193. Measurement and Weight of the Sirup.— The methods used for juice apply with sirup. The weight of the sirup is not usually required, except in taking account of the stock of the material in process. Deerr uses the weight of sirup in his method of calculating the available sugar.[2]

It is the present tendency of the factories, in view of improvements that have been made in the defecation, to hold the sirup only long enough to meet the pan requirements.

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[1] The intervals between the hours 6 to 12 A.M., 12 to 6 P.M., etc., are termed " watches."

[2] Bul. 41, Hawaiian Sugar Planters' Expt. Sta.

This makes accurate routine measurement difficult if feasible.

The sirup must be occasionally measured in taking account of the sugar in process for the run reports. For this purpose the tanks should be gauged and the volume per inch of depth be tabulated. In these measurements it is more convenient to note the "inches out" and figure the sirup in the tank by difference.

194. Measurement and Weight of the Massecuites. —It is difficult to accurately measure or weigh a massecuite with the methods of manufacture prevailing in modern factories. When the massecuite is discharged into cars, direct weighing may be resorted to, but special care must be observed in taring the empty cars. The extra labor involved in the weighing, and the difficulty in securing satisfactory laborers, usually prevent this work in most factories.

It is also impracticable to accurately measure the massecuite when it is discharged directly into the centrifugal mixers or into crystallizers. Under these conditions the weight can only be calculated approximately. (See page 345.)

The measurements in the mixer and especially in the crystallizers should be made immediately on striking the massecuite, on account of its increase in volume after stirring or further crystallization.

The measurement or weight of the massecuite is usually only required at the end of a " run " or period for calculating the quantity of sugar in process of manufacture. In very large factories the errors in these measurements, when carefully made, are so small as compared with the amount of material in process that they may be neglected.

A sample of the massecuites should be drawn, when striking, for analyses for use in making the necessary calculations and for the guidance of the sugar-maker in the conduct of the pan-work.

195. Sugar-weights.—The chemist should from time to time check the weighing of the sugar, since a small error per package may appreciably affect his calculations. Automatic scales are coming into extensive use in weighing dry white sugar, i.e., granulated sugar. An empty bag

forms a part of the counterpoise, when using this class of packages, and does away with other allowance for tare. These scales give very reliable weights.

The workmen at the scales usually fill the packages to "down" weight, and where sugar is packed very fast this surplus weight may amount to a large quantity in the course of the manufacturing season, and add to the apparent mechanical losses.

Dependable automatic scales are now made for raw sugar. These use a mechanical arrangement to regulate the flow of the sugar into the weighing-hopper and to adjust the "dribble" or last small quantity. One type of these scales will accurately weigh more than 80 bags of 325 lbs. of raw sugar per hour. This method of weighing reduces the "undetermined loss." Richardson's and the "Libra" scales are in use in Cuba.

195a. Measurement of the Molasses.—The measurement of the molasses is accompanied by difficulties arising from the nature of the material itself. Molasses is very viscous and drains very slowly from the containers, making successive measurement in a tank uncertain. Further, heavy molasses occludes considerable quantities of air. This occlusion of air raises the question of a definition of the commercial gallon of final molasses.

Molasses that has been reduced with water preparatory to reboiling is readily measured in the tanks. Final molasses should be weighed in tank-cars when possible, on account of its importance in the factory control. A "wantage table" is given on page 498 for the measurement of the molasses in horizontal cylindrical tanks (tank-cars). The amount of air occluded varies with the container, the method of filling it and the period that elapses between filling and measuring. In an experiment by the writer, a molasses weighed less than 11 lbs. per U. S. gallon, measured immediately after filling a tank-car and the air-free weight of the same molasses was 12 lbs. This indicates the importance of experimental data as a basis of calculation of the weight of the molasses in meeting local conditions. A float measurement, using a copper float, is the most satisfactory for molasses stored in very large tanks.

196. Mill Extraction.—The quantity of juice or sugar removed from the cane by the mills, the mill extraction, is usually expressed in two ways, viz., (1) The weight percentage on the cane of the mixed juice calculated to terms of the density of the normal juice. This expression is gradaully being superseded by the second, which has become quite reliable through improvements in analytical and milling methods. (2) The weight of sucrose extracted in the juice per cent of the weight of sucrose in the cane. This number cwes its increasing use not only to the fact that it directly indicates the sucrose extraction, but also because it is less influenced by the variations in the composition of the cane. This number was formerly based upon the direct analysis of the cane or upon a sucrose number derived in the incorrect assumption that the juice as it exists in the cane is of uniform composition.

(1) *Extraction in Weight Terms of the Cane and Normal Juice.*—Divide the weight of diluted or mixed juice (**169**) by the weight of the cane and point off for percentage, to ascertain the per cent dilute extraction; calculate the dilution per cent cane (**207**) and subtract this number from the dilute extraction number. The remainder is the extraction of normal juice per cent cane.

(2) *Extraction in Percentage Terms of the Weights of Sucrose in the Cane and the Extracted Juice.*—Calculate the weights of sucrose in the diluted juice and in the bagasse. The weight of the bagasse is ascertained by subtracting the weight of the diluted juice from the sum of the weights of the cane and saturation-water. The sum of the weights of sucrose in the extracted juice and the bagasse is the weight of sucrose in the cane. The weight of sucrose in the extracted juice divided by that in the cane and the quotient multiplied by 100 is the extraction number in terms of the sucrose in the cane and in the extracted juice.

(3) *Extraction in Dry Milling, i.e., without Saturation.*—The calculations are similar to those of (1) and (2) except that no water of dilution need be considered.

Example illustrating methods of calculating the extraction:

Tons of cane ground.....................3254,
Tons of diluted juice extracted...........3450
Tons of saturation-water applied to the
    bagasse.............................. 877
Degree Brix of the crusher juice.......... 19.21
Factor for reducing the Brix of the crusher
    juice to that of the normal juice (**168**).. 0.97
Degree Brix of the diluted juice.......... 14.52
Per cent sucrose in the diluted juice...... 11.98
Per cent sucrose in the bagasse.......... 2.90

(1) Brix of the normal juice $= 19.21 \times 0.97$..... 18.63

Dilution per cent diluted juice $= 100(18.63$
    $-14.52) \div 18.63 =$ (*See* **205**)........... 22.06

Dilute juice extraction $= 3450 \div 3254$
    $\times 100 =$ 106.02

Dilution per cent cane $= 106.02 \times 0.2206 =$ 23.39

Mill extraction, normal juice per cent
    cane $= 106.02 - 23.39 =$................ 82.63

(2) Weight of bagasse $= (3254 + 877) - 3450 =$ 681   tons

Sucrose in the bagasse $= 681 \times 0.029 =$..... 19.745 tons

Sucrose in the extracted juice $= 3450 \times$
    .1198 =$ .... 413.31 tons

Sucrose in the cane $= 413.31 + 19.745 =$.... 433.055 tons

Mill extraction, sucrose extracted per cent
    sucrose in cane, $413.31 \div 433.055 \times 100 =$ 95.44

Résumé:

Diluted juice extraction, per cent cane.... 106.02
Dilution, per cent cane................. 23.39

Extraction, normal juice per cent cane.... 82.63

Extraction, sucrose extracted per cent su-
    crose in the cane.................... 95.44

197. Dry-milling Extraction-number.—The follow-
ing method of estimating the extraction obtained by the
different mills of a train, without saturation, is some-

times used in supplying information for adjusting the mills:

Juice extracted per cent cane = (per cent fiber in bagasse − per cent fiber in the cane) ÷ per cent fiber in the bagasse × 100. This method is subject to error arising from the difficulty experienced in sampling the bagasse as it passes from mill to mill.

198. Saturation. Maceration. Imbibition.—The quantity of water used in saturating the bagasse can only be determined with certainty by weighing or by accurate measurement. An estimation of the water is sometimes made by an inferential method similar to that used in estimating the weight of the cane. Inferential methods for the water are open to the same objections as those for the weight of the cane.

The water should be actually weighed and its percentage on the cane calculated or it should be measured and calculated over to weight. The percentage should be in terms of the weight of the cane.

The dilution in terms of the normal juice is used largely in Java and the Hawaiian Islands to indicate the saturation. The percentage of water on the weight of the cane is also used in Hawaii.

Saturation per cent cane = weight of the water ÷ weight of the cane × 100.

Dilution per cent normal juice = (Brix of normal juice − Brix of diluted juice) ÷ Brix of diluted juice × 100.

There is much confusion among sugar-chemists in the method of stating the amount of saturation-water used. The author suggests the adoption of the expression "Per cent dilution" for the water as calculated from the density of the juices, since this represents the water, in terms of the total juice, that must actually be evaporated on account of the use of saturation. For the saturation-water, as calculated from its weight and that of the cane, the expression "Per cent saturation" or "maceration" is suggested. Sugar-house reports, in indicating the quantity of water used, should employ both the expressions "Per cent dilution" and "Per cent saturation."

CONTROL OF THE SUGAR-BOILING.

199. Control of Vacuum-pans and Crystallizers.—
The control of the vacuum-pans and crystallizers requires
rapid analytical work of moderate accuracy.

The analysis of the sirup as made in the daily routine
work, or in its stead the analysis of the juice, and that of the
molasses indicate the quantity of the latter to be drawn
into the pan to produce a massecuite of the desired purity.
If a cut strike is to be boiled, the purity of the above masse-
cuite and that of the molasses to be boiled-in, supply
the data for calculating the quantity of each of these re-
quired to produce a massecuite of a certain purity. These
calculations are made by the following formula, with suffi-
cient accuracy for the purpose:

   Let 100 = total weight of massecuite in the strike;
         P = purity of the sirup, or, in the case of a cut strike,
              that of the massecuite left in the pan;
         p = purity molasses to be boiled-in;
         M = purity of the required massecuite;
         x = percentage by weight of that part of the strike
              to be formed of molasses;
   100 − x = percentage of the strike to be derived from sirup
              or from a previous boiling;

$$\therefore \; x = \frac{100(P-M)}{P-p}.$$

The proportions of the materials used in making a mixture
of a certain purity may also be quickly calculated by the
diagram method, page 347. It is not feasible in pan-work
to base the calculations on actual weights. The approximate
densities of the massecuite footing, for example, and the mo-
lasses to be boiled in should, however, be considered.

A sample of the mixed massecuite should be brought to the
laboratory immediately the strike is dropped. A portion of
this should be dissolved in water to form a solution of about
15° Brix, and its apparent purity should be determined. A
second portion should be purged in a laboratory centri-
fugal and the purity of the molasses be determined as
above.

If dry lead defecation is used in this work, the labor of

calculating the apparent coefficient of purity may be avoided by the use of Horne's table, page 526.
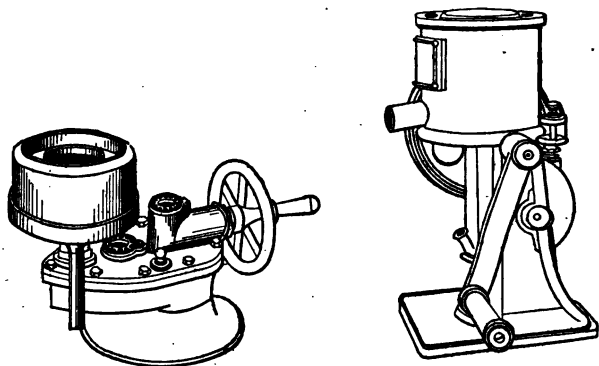
FIG. 87.
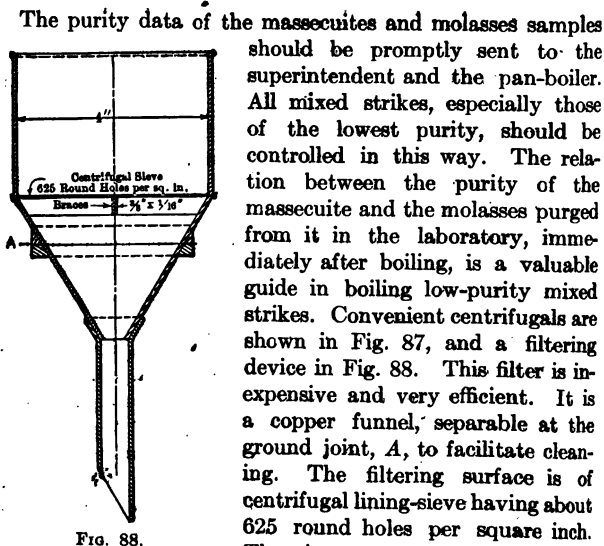
The purity data of the massecuites and molasses samples

FIG. 88.

should be promptly sent to the superintendent and the pan-boiler. All mixed strikes, especially those of the lowest purity, should be controlled in this way. The relation between the purity of the massecuite and the molasses purged from it in the laboratory, immediately after boiling, is a valuable guide in boiling low-purity mixed strikes. Convenient centrifugals are shown in Fig. 87, and a filtering device in Fig. 88. This filter is inexpensive and very efficient. It is a copper funnel, separable at the ground joint, A, to facilitate cleaning. The filtering surface is of centrifugal lining-sieve having about 625 round holes per square inch. The sieve must be supported by braces. The funnel is used in connection with a vacuum-

filtering flask or a bell-glass and plate. Connection is made with the vacuum system of the factory.

Very often this method of control will indicate whether the pan-boiling is good or poor. When a low-purity massecuite yields a high-purity molasses, on immediate purging, it indicates poor boiling. A few days' experience with the pans, following the work with these control-tests, will usually indicate whether the sugar-boilers are obtaining the best results the pans and material are capable of yielding.

200. Inversion.—In the manufacture of white sugar from the cane, there is often a loss of sucrose due to inversion, and which varies with the acidity of the juice. In raw-sugar factories, except in the event of serious delays, there is little if any inversion of the sucrose, since the juice is limed to neutrality to phenol. The alkaline condition gradually changes to neutrality in the storage-tanks.

Inversion of sucrose is caused by all acids, to a greater or less degree, the mineral acids inverting with great rapidity and some of the weaker organic acids scarcely at all.

Many inorganic salts and salts of organic acids, though the latter feebly, exercise an invertive action on sucrose.

Heat alone will invert sucrose in water-solution, but more rapidly in the presence of air.

The product of the inversion, invert-sugar,[1] is composed of equal parts of two sugars, viz.: dextrose and levulose. The properties of these sugars are given in page 56. These sugars are acted upon by the lime and heat in the defecation, and levulose is often in part decomposed. The decomposition of this sugar is very noticeable in the alkaline defecation and the dark color of the juice is due to the decomposition products. Provided there has been no decomposition of glucose, a comparison of the ratio of the glucose to the sucrose of the juices, etc. under examination, will usually indicate whether inversion has taken place or not. The

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[1] In cane-sugar manufacture, the invert-sugar and other reducing substances in the juice and products are usually called glucose, and for brevity this expression is used in this book.

difference between the glucose ratios is not a measure of inversion except in a general way.

From the above remarks, it is evident that loss of sucrose through inversion cannot always be detected and estimated from the percentages and quantities of sucrose and glucose in the raw materials and products. It can usually be detected, however, as losses will not often balance one another.

In using the following formulæ, for the calculation of inversion, the above considerations should be kept in view:

Sucrose inverted in the evaporation, etc.—The inversion, except in the diffusion-battery, may be calculated by the following extended formula of Dr. William Stubbs of the Louisiana Experiment Station:

Let a = sucrose per unit of juice;
  b = glucose per unit of juice;
  c = sucrose per unit of sirup or massecuite, etc.;
  d = glucose per unit of sirup or massecuite, etc.;
  E = the total weight of juice (pounds);

Let s = total sucrose removed in the sugars and by losses
    (pounds);
  g = total glucose removed in the sugars and by losses
    (pounds);
  x_1 = total inversion;
  x_2 = loss in concentration of the juice to sirup or 1st
    massecuite;
  x_3 = loss in concentration of the juice to massecuite.

(1) $$x_1 = \frac{95[E(ad-cb)+cg-ds]}{100c+95d}.$$

(2) When neither sucrose nor glucose is removed, as in the concentration of juice to sirup or 1st massecuite, the formula reduces to

$$x_2 = \frac{95E(ad-cb)}{100c+95d}.$$

(3) When there is no glucose removed in the sugars, $g=0$, and the formula reduces to

$$x_s = \frac{95[E(ad-cb)-ds]}{100c+95d}.$$

The following general formulæ for inversion by Lieut. A. B. Clements, U.S.N., are modifications of Dr. Stubbs' formula:

(1) x = sucrose inverted per cent sucrose in the original juice;

S = sucrose removed in sugars and by losses per cent sucrose in the original juice;

g = glucose removed in sugars and by losses per cent sucrose in the original juice;

r_1 = per cent glucose in the juice ÷ per cent sucrose in the juice × 100;

r_2 = per cent glucose in the massecuite or molasses, etc., ÷ per cent sucrose in ditto × 100.

$$x = \frac{100(r_2-r_1+g)-r_2 S}{r_2+\dfrac{10000}{95}}$$

$$\frac{10000}{95}=105.263.$$

(2) Multiplying the above equation by a, the per cent sucrose in the original solution, we obtain x in terms of the weight of the juice:

$$x = a\frac{r_2-r_1+g-r_2 S}{r_2+\dfrac{10000}{95}}.$$

(3) Calculation of inversion in terms of the glucose:

x = inversion per cent juice;

F_1 = per cent sucrose in the juice ÷ per cent glucose in ditto;

F_2 = per cent sucrose in the sirup or massecuite, etc., ÷ per cent glucose in ditto;

S_2 = sucrose removed in the sugars, etc., per unit of glucose in the juice;

g_2=glucose removed in the sugars, etc., per unit of glucose in the juice;

b=glucose per cent juice.

$$x = b\frac{F_1 - F_2 + F_2 g_2 - S_2}{1 + \frac{100}{95}F_2},$$

$$\frac{100}{95} = 1.05263.$$

201. Formulæ for the Calculation of Inversion in the Diffusion-battery.[1]

(1) $F_1 = \dfrac{\text{per cent sucrose in the diffusion-juice}}{\text{per cent glucose in the diffusion-juice}}$;

  $F_2 = \dfrac{\text{per cent sucrose in the normal juice}}{\text{per cent glucose in the normal juice}}$;

  b=per cent glucose in the diffusion juice;

  $x = b\dfrac{F_2 - F_1}{1 + \dfrac{100}{95}F_2}$ =inversion in the battery per cent diffusion-juice.

(2) a=per cent sucrose in the diffusion-juice;

  $r_1 = \dfrac{\text{per cent glucose in the diffusion-juice}}{\text{per cent sucrose in the diffusion-juice}} \times 100$;

  $r_2 = \dfrac{\text{per cent glucose in the normal juice}}{\text{per cent sucrose in the normal juice}} \times 100$;

  $x = a\dfrac{r_1 - r_2}{r_2 + \dfrac{10000}{95}}$ =inversion in the battery per cent diffusion-juice.

(3) $[p - (100-e)P].95 = x$ =inversion in the battery per cent diffusion-juice. p=per cent glucose in diffusion juice; P=per cent glucose in the normal juice $\div 100$; e=

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[1] Formulas (1) and (2) are based upon Dr. Stubbs' formula.

evaporation necessary to concentrate the diffusion-juice to
the same percentage of solids as in the normal juice. To
obtain e subtract the degree Brix of the diffusion-juice from
that of the normal juice and divide the remainder by the
degree Brix of the normal juice. Multiply the quotient
by 100.

This formula only gives approximate results. The error
amounts to less than 15 lbs. sucrose per 1,000,000 lbs. of
juice when the inversion does not exceed 1 per cent (G. L.
Spencer).

DIVISION OF THE SEASON INTO PERIODS.

**202. Division of the Manufacturing Season into
" Runs " or Periods, and Estimation of the Yield of
Sugar.**—In order to properly present the laboratory and
manufacturing data, to the management of the sugar-house,
the season should be divided into a series of short periods,
or "runs." In a small factory that is not operated on
Sundays, the periods may conveniently end with that day,
making a run of one week. Under similar conditions the
periods in a large factory may be two weeks. In many
factories it is customary to close a period's work when the
machinery is necessarily stopped on account of bad weather
or a mishap.

The author prefers to close a period arbitrarily, after a
certain number of days' work, in order that the periods of
one crop may be readily compared with those of previous
years. In view of the very great labor involved in securing
the data, making the calculations and preparing the reports,
a period of two weeks is a convenient one. Moreover, this
permits setting apart a certain day of the week for stock-
taking.

If the machinery is idle, it is only necessary to measure the
quantity of material in process at the various stations,
and calculate their commercial sugar-value.

If the factory is in operation the following is the mode
of procedure:

The chemist should prepare slips of paper with the num-
bers or other designations of the tanks and various pieces

of apparatus, conveniently arranged for noting the measurements at the stations.

If the factory day ends at midnight, for example, the chemist, an ass. 'ant, and the laboratory helper, provided with sample cups and a measuring-rule, should at that time go systematically through the factory drawing samples of the juice, etc., and measuring the quantity of material at the various stages of manufacture. This stock-taking should begin with the juice and end with the sugar, and must include all material in process, even the sugar in the centrifugals. It is usually more convenient to measure the depth of the empty space in the tanks, rather than that of the liquor. By using a very small measuring-cup for sampling, one cupful, for example, may be drawn from a quarter of a tank of sirup, two cupfuls from half of a tank; and so on, thus forming a composite sample that will represent the average composition of the sirup with a fair degree of accuracy. If the tanks are of different sizes, the quantity drawn from each must be varied accordingly.

The volume of juice in the multiple effects should be estimated and may be considered a constant quantity from run to run, when the apparatus is in use. The material in the multiple effect may be measured when liquidated into tanks or the apparatus may be calibrated with water at the beginning of the season. The density of the sirup in the vessels of the evaporator should be ascertained from time to time as a guide in calculating the sugar value.

By prearrangement with the sugar boiler, certain tanks of sirup (meladura) and molasses may be omitted as such from the stock and be used to complete strikes of massecuite then in the pans. Thus these massecuites need not be measured until they reach the crystallizers or if immediately purged, the sugar and molasses may be separately considered. If this arrangement is not feasible, the sugar boilers should, at the whistle signal, note the depth of sirup and molasses in the tanks and indicate the approximate depth of massecuite in the pan by chalk marks. The condition of the massecuite should be noted or, preferably, proof-stick samples should be drawn for analysis. The quantity of sugars in the centrif-

ugals, hoppers and bins should be noted, also the last serial package number.

Stock-taking in a large factory need require but a few minutes if the above scheme be followed. The results are practically as accurate as were the stock taken during a shut-down.

When the run report is called for to include a certain date, the work of stock-taking may be facilitated, should it be known that the factory will be shut down a day in advance or a day later for cleaning or other reason. In this event the cane ground before or after the date is either carried as stock and figured to sugar or its product is deducted as the case may require.

Having secured the necessary data and samples and the analysis of the latter, the calculations may be made as follows:

Juice and Sirup.—Since the raw juice has all the processes of manufacture ahead of it, its commercial sugar value should be estimated from the previous experience of the factory. The available sugar method given on page 305 in connection with an efficiency number may be used. If there is no record of the previous experience of the factory, the yield may be based upon calculations by the commercial sugar formula, page 342, taking into consideration the probable or an estimated loss in manufacture. These remarks apply more especially to the first run of the factory, after which the run figures are more accurate, and further there is experience in the factory to guide one.

A slightly higher yield may be expected from the sirup than raw juice on account of its having been purified. This is also true of the clarified juice. The table, page 515, is a convenient guide in making these estimates.

Massecuites and Sugars.—If the massecuite has been boiled without the addition of molasses, its sugar value may be calculated as in the cases of the juice and sirup. If, however, molasses has been boiled-in or mixed with the massecuite in crystallizers, the following formula should be used:

Let x = per cent of commercial sugar (sugar-value) to be obtained from the massecuite;

B = degree Brix of the massecuite;

Let P = polarization of the massecuite;
p = polarization of the commercial sugar;
S = solids per unit of the commercial sugar;
M = coefficient of purity of the final molasses.

Then
$$x = \frac{100P - BM}{p - SM}.$$

This formula gives accurate results only when the true polarization, true Brix and purity are used. For the purposes of the estimates it is usually sufficiently accurate to use the apparent polarization, etc. With low-purity massecuites, the calculated results differ but little from the actual yield at the centrifugals.

It will be noted that the purity of the final molasses is used in these estimates. This is advisable as it simplifies the calculations. If but one grade of sugar is made, the calculation is simply a substitution of values in the formula. If, however, more than one grade is made, e.g., 96° sugar and 2ds, it is necessary to know in what proportions these sugars are made, alloting its proportion to the 96° test sugar and reducing the remainder to terms of the second sugar

In reporting estimates for the period or run, it is customary in addition to the general statistics of the manufacture and the analytical data, to report the yield of sugar as follows:

1st sugar per cent of the cane.
2d   "   "   "   " "   "
Total "   "   "   " "   "

1st sugar, sucrose retained per cent of sucrose in the juice.
2d   "   "   "   "   " "   "   " "   "
Total "   "   "   "   " "   "   " "   "

The sugar is also occasionally reported as follows:
1st sugar per cent of sucrose in the juice.
2d   "   "   "   "   "   "   " "
Total "   "   "   "   "   "   " "

This is not a very satisfactory statement of the yield, since in order to be comparable with those of other runs the figures must be reduced to terms of sugars of the same polarization.

The statement giving the sucrose retained in the commer-

cial sugar per cent of the sucrose in the juice, shows at a glance, in comparisons, the relative quality of the work. This form of statement is in very general use.

Final molasses.—In many factories that are located at a distance from favorable markets, the final molasses are run to waste and the only check the chemist has upon this material is his analytical work. Where the molasses is pumped into large tanks, from which shipments are made from time to time, data of the total volume and average composition may often be obtained. It is often difficult to secure information for accurately distributing this product among the various runs, or periods.

The average composition is best ascertained from analyses of samples of each shipment, but in addition to such analyses frequent control-tests should be made of the molasses as it is pumped from the factory. Where the weight of the molasses is ascertained by weighing it in tank-cars, these cars should always be tared before filling them, as owing to the viscosity of the molasses the workmen frequently fail to entirely empty the tanks.

203. Losses of Sugar in the Manufacture.—The usual sources of loss are in the bagasse, filter-press cake, and through decomposition and entrainment in the evaporation. Other possible sources are by inversion, fermentation, and the so-called mechanical or undetermined losses.

The bagasse.—The loss in the bagasse is calculated from the estimated weight of the material and its analysis.

The weight of the bagasse is often estimated as the difference between the weight of the cane and that of the normal juice. This does not usually give a correct result when saturation is practiced, since the bagasse may leave the third mill heavier than it would be otherwise. In this case if the weight of the saturation-water be known, the bagasse is the weight of the cane+weight of saturation-water—weight of the mixed diluted juice.

It may occur that the weight of the saturation-water is not known. In this event an inferential method must be used. Fiber per cent cane×100÷fiber per cent bagasse =bagasse per cent cane. The uncertain quantity in this calculation is the percentage of fiber in the cane.

Filter-press Cake.—The loss of sucrose is calculated from the analysis and weight of the press-cake.

The weight of the press-cake is usually estimated from the actual average·weight of the contents of several filter-presses. When this is not practicable, the cake from a single chamber or frame of the press is weighed from time to time to obtain an average weight and this number is multiplied by the number of cakes in the press, to obtain the total weight. The cake weighs approximately 60–62 lbs. per cu. ft.

There is a loss of sucrose in the juice absorbed by the filter cloth. This is usually included with the unknown losses. This quantity varies with the filter-press methods. It will vary from almost nothing with double filter-pressing to 0.5 lb. or more per filter cloth.

Inversion.—Inversion may be estimated by the formulæ on page 327, provided no glucose has been destroyed. It may also be estimated by reducing the analyses to a dry basis. For example: A sirup has a coefficient of purity of 85, that is 85 per cent of its content of solid matter is sucrose; after evaporation to massecuite the purity falls to 84.5. This indicates that 0.5 per cent of its solid matter has been destroyed or inverted. This assumes the solid matter to be a constant.

Glucose is usually destroyed to some extent in the manufacture, therefore when actual or calculated weights of the materials can be obtained it is preferable to figure a glucose balance as well as a sucrose balance to obtain light on the losses.

Changes in the saline coefficient are sometimes used in tracing losses either by inversion or mechanically. Zimmermann [1] suggests a method based upon the persistence of certain of the soluble salts throughout the manufacture. (See page 349.) He determines the sucrose by the Clerget method and the ash as sulphated ash. He transfers the ash to a beaker and precipitates the lime, etc., with ammonium oxalate in the presence of ammonia, then washes out the soluble sulphates left in the precipitate and determines their quantity

by- difference. The calculations are illustrated by one of
Zimmermann's examples:

Mill-juice· Sucrose, 10.5 per cent; soluble sulphates in
the ash, 0.31 per cent; $0.31 : 10.5 = 1 : x$ and $x = 33.87$, the
ratio for juice. Sirup: Sucrose, 46.3 per cent; soluble sul-
phate in the ash, 1.38 per cent; $1.38 : 46.3 = 1 : y$ and y
$= 33.55$, the ratio for sirup. The change in the ratio from
juice to sirup is $33.87 - 33.55 = 0.32$, corresponding to 0.32 per
unit of sulphates. Then $33.87 : 0.32 = 100 : x = 0.94$, per
cent loss on sucrose in the juice.

This is evidently a very exaggerated example. The soluble
sulphates are much higher than the usual total ash and the
loss is excessive. This method is quoted to call attention to
this class of investigations.

Entrainment.—The loss by entrainment may be estimated
by Norris' table, page 434. This loss is estimated from the
analysis of the water flowing from the condenser and its
weight as calculated from the temperature changes and the
quantity of water evaporated. Detailed instructions are
printed with the table.

LABORATORY AND FACTORY RECORDS.

204. Test Books and Records.—It is difficult to plan
a set of books and forms without knowing something of the
needs of the owners, the force of chemists available for con-
trol and whether this control is to be partial or fairly complete.

The usual reports include: (1) A slip for the Manager,
Superintendent and Engineer, giving preliminary data of the
mill work and control analyses of the juices, the output of
sugar and the fuel consumption; this should be supplemented
by frequent reports to the Engineer on the analysis of the
bagasse. (2) The preliminary report should be followed by
what may be termed an "operating report," which should
include data covering the entire line of chemical control and
the manufacture. This should include mill and manufactur-
ing statistics. (3) Run reports at stated intervals, giving a
résumé of all data collected both for the run and to date,
including a sucrose balance and a statement of yield and
losses. The data should be full enough to indicate the
methods of manufacture and supply the owners a permanent

record of methods. Working and lost time should also be reported to indicate what portion of the factory's capacity is being utilized. (4) Laboratory records: (a) Used in the analytical work. (b) Extraction figures, etc (c) Records of pan-work. (d) Unit-book, used in recording the quantities of materials, products and by-products and in calculating weighted averages.

Printed forms should be supplied for the entries in the routine laboratory work. A large space should be provided in these forms for the figuring with a view to tracing errors. The use of printed forms also promotes systematic work. A loose-leaf binder is convenient for these forms and a sheet should be used each day. All figuring should be on the sheets or in special books and never on scraps of paper.

It is advisable to have printed forms for calculating and recording mill data, operating and lost time and fuel consumption. A special blank should be posted at the mills for reporting the delays and their causes. These figures should be tabulated from time to time for the use of the General Manager and the Chief Engineer.

The daily laboratory reports, for a fairly complete control, should include: (1) Analyses of the diluted, normal (calculated) and residual juices. (2) Fiber and sucrose in the cane. (3) Analysis of the sirup. The Brix is for the control of the evaporation and the purity coefficient for that of the defecation. (4) Analyses of the massecuites and molasses to control the injection of molasses and the work of the crystallizers. (5) Moisture and polarization of the sugars and occasionally ash tests. The moisture has a bearing on the storage qualities of the sugar; the polarization must meet market requirements; the ash is an additional check upon the purification of the juice. (6) Analysis of the final molasses to meet market conditions and to control the pans, crystallizers and centrifugals. (7) Analysis of the filter-press cake to control the loss of sugar. (8) Analyses of the bagasse at frequent intervals, including moisture, fiber, and sucrose tests, for mill control. (9) Frequent examination of the feed-water for sugar, for the protection of the boilers. (10) Entrainment tests in the condenser water, to protect against carelessness in the evaporation and in the pan-boiling.

The manufacturing data that should be included in this report are records of the cane ground per hour and per day; operating and lost time; saturation and dilution; mill extraction; available sugar, sugar in process and sugar dried; fuel consumption. These figures should be for the day and to date.

A convenient arrangement of a run report is to place the manufacturing data on the left-hand side of the sheet and the analytical data and figures derived from them on the right.

SUGAR-HOUSE CALCULATIONS.[1]

205. Introductory.—All materials to be dealt with by the chemist are composed of sucrose and non-sucrose, the latter including water, dextrose, levulose, organic non-sugars, (marc, etc.) and inorganic matter (ash). Certain of these substances persist throughout the manufacture, others through but one or two stages of it. A knowledge of the proportions of these substances in the original material, products and by-products, is the basis for the construction of algebraic equations, with which yields, quantities, capacities, etc., may be calculated.

For the purposes of the usual calculations, in addition to the proportions in which the various constituents are present, certain relations between the constituents themselves are often required, such as purity coefficient, saline coefficient, etc. The problems are very simple when a constituent of the original material passes practically unchanged through the processes, e. g., the fiber in dry milling.

The following formula illustrates the principles involved in many of the sugar-house calculations.[1] The water used in saturating the bagasse in milling cane dilutes the extracted juice; the percentage of this dilution is ascertained by means of an equation based upon the fact that the solids (Brix) of the extracted normal (undiluted) juice are present in the diluted juice:

Let 100 = the weight of diluted juice;
        b = degree Brix of diluted juice;
        B = degree Brix of normal juice;
        x = weight of dilution-water in diluted juice;
   $100 - x$ = the weight of normal juice,
then

  $100\, b = B(100 - x)$ and $x = 100 - 100b/B = 100(B - b)/B$.

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[1] The mark " / " is used to indicate division.

This is the usual dilution formula and is used because it is the diluted juice that is weighed or measured. The value of x multiplied by the percentage of dilute juice extracted from the cane gives the dilution in terms of the weight of the cane.

In a similar way, calculations may be based upon the fiber of the cane, the dry matter of the press-cake, the ash or a constituent of it, etc.

Since many of the numbers ascertained in sugar analysis are not absolute, many of the results of sugar-house calculations based upon them are approximations, but are usually sufficiently accurate for the purposes of the manufacturing control. These considerations apply especially to massecuites and molasses in whose analysis absolute results cannot be expected.

The full work of deducing the formulæ is usually given in the following paragraphs, with a view to assisting the beginner in the construction of formulæ that are not given or that are necessitated by special conditions.

206. Dry-milling Formula.—The fiber or marc is the constant:

Let $100 =$ the weight of the cane;

$\quad B =$ the weight of the bagasse from 100 cane;

$\quad F =$ the percentage of the marc in the cane;

$\quad F' =$ percentage of marc in the bagasse;

$\quad x =$ percentage of juice extracted;

(1) $x = 100 - B$;　(2) $F'B = 100F$; whence $B = 100F/F'$;

substituting the value of B in (1)

$$x = 100 - 100F/F' = 100(F' - F)/F'.$$

The similarity of this formula and that for calculating dilution (**207**) is noticeable. This should be expected since in the one the constant (Brix) is diluted and in the other the constant (marc) is concentrated, i.e., its percentage relation to the bagasse as compared with cane increases.

207. Dilution Formulæ.—The formula for the dilution of the mill-juice in terms of the diluted or mixed juices has been given in the Introductory (**205**). To reduce this number and the following dilution number to percentage terms of

the weight of the cane, it is necessary to multiply the values of x by the percentages of diluted and normal juice, respectively. The dilution per cent normal or undiluted juice is calculated as follows:

Let $100 =$ the weight of normal juice;
$B =$ the Brix of the normal juice;
$b =$ the Brix of the diluted juice;
$x =$ the percentage of dilution in terms of the normal juice,

then $100 + x =$ the weight of the diluted juice, and since all the solids (Brix) of the normal juice are found in the diluted juice, $b(100+x) = 100\ B$ and $x = 100\ B/b - 100 = 100(B-b)\ /b$. This number is used in certain countries to indicate the quantity of maceration-water that has been used, though in fact it only indicates the part of the water that has passed into the juice.

208. Concentration and Evaporation Formulæ.— These formulæ are similar to those for dilution and are derived in the same way:

Let $100 =$ the weight of the juice, etc.;
$b =$ the Brix of the juice;
$B =$ the Brix of the concentrate;
$x =$ the percentage, by weight, of water evaporated;
then $100b = (100-x)B$, whence
$x = 100(B-b)/B$.   (See **311**.)

The percentage of evaporation by volume is derived as follows:

Let $100 =$ the volume of the juice, etc.;
$b =$ the Brix of the juice of g specific gravity;
$B =$ the Brix of the concentrate of G specific gravity;
$x =$ the percentage, by volume, of water evaporated;
then $GB(100-x) = 100gb$, and
$x = 100 - gb/GB$, the volume of water evaporated. (See **312**.)

209. Commercial Sugar Formulæ.—(A) This formula has a wide application in the sugar-house control and

in the estimation of the capacities required in crystallizers, etc.:

   Let x = the percentage yield of commercial sugar of p polarization and S per cent dry matter;
      100 = the weight of the primary material (massecuïte, molasses, etc.) of P polarization and B per cent dry matter (Brix);
      M = coefficient of purity of the residual molasses;
   then $P - px/100$ = the weight of sucrose in the molasses;
      $B - Sx/100$ = the weight of dry matter (Brix) in the molasses.

   Since the coefficient of purity of a sugar material is the percentage of sucrose in its dry matter we have

$$M = 100\frac{P - px/100}{B - Sx/100};$$

clearing of fractions, transposing and reducing,

$$x = \frac{100P - BM}{p - SM/100},$$

the yield of commercial sugar. If the product is refined sugar of 100° polarization, as is customarily assumed in refinery work, the formula reduces to

$$x = \frac{100P - BM}{100 - M}.$$

   (B) This formula is applicable in the calculation of the yield of sugar from massecuïtes, molasses, etc., and gives percentages in terms of the primary material.

   Let x = the percentage of commercial sugar of P' purity coefficient and b per cent of dry matter;
      100 = the weight of primary material, P its coefficient of purity and B its degree Brix;
      M = the coefficient of purity of the residual molasses.

Then $BP/100 =$ the weight of sucrose in the material;

$bx/100 =$ the weight of dry matter in the sugar;

$$\frac{100bx}{100 \times 100} \times \frac{P'}{100} = \frac{P'bx}{10000},$$ the weight of sucrose in the sugar;

$B - bx/100 =$ the weight of solids in the molasses;

$$\frac{BP}{100} - \frac{P'bx}{10000} =$$ the weight of sucrose in the molasses.

As in the preceding sugar formula, an equation based upon the coefficient of purity of the residual molasses is formed:

$$M = 100 \left(\frac{BP}{100} - \frac{P'bx}{10000} \right) \div \left(B - \frac{bx}{100} \right);$$

clearing of fractions, transposing and reducing, we have

$$x = 100 \frac{P - M}{P' - M} \times \frac{B}{b}.$$

(*C*) This formula has the same applications as the preceding. It is derived in the same way, but is based upon moisture-free materials:

Let $x =$ the percentage yield of anhydrous sugar in terms of the dry matter (Brix) in the primary material, and let the other letters have the same meaning as in the previous formula (*B*).

Then $100 - x =$ the dry matter (Brix) of the residual molasses;

$P'x - M(100 - x) = 100P$, whence $x = 100 \dfrac{P - M}{P' - M}$, the percentage of anhydrous sugar in terms of the dry matter in the primary material.

The above formulæ may be applied in the calculation of the yield of sugar from the cane or juice, but it is necessary to take into account the losses in manufacture in order to make a correct estimate. The "available sugar" formulæ (**185**)

are more suitable for such estimates, since they take the losses into consideration. These formulæ find their chief uses in calculating the yield of sugar in process in massecuites, etc.

210. Crystallizer Capacity.—The commercial sugar formulæ may be used in estimating the capacity required in certain machinery, notably pans, crystallizers and molasses-tanks, using true solids and sucrose in accurate work.

Let it be required to estimate the quantity of crystallizer massecuite of 94° Brix and 60° purity that would be produced from clarified juice of 20° Brix, 18 per cent sucrose and 90° purity, the sugar that has been extracted having an analysis of 96° polarization and 99 per cent dry matter: Using formula (A), 209, we have

$$x = \frac{100 \times 18 - 20 \times 60}{96 - 99 \times 60/100} = 16.39$$

sugar per cent of the weight of the juice. Let the juice be 80 per cent of the weight of the cane, then $16.39 \times .80 = 13.11$ sugar per cent cane. The sugar contained 99 per cent dry matter, therefore $13.11 \times .99 = 12.98$ per cent dry sugar. The juice contains $20 \times .80 = 16$ per cent dry matter (Brix solids) on cane and $16 - 12.98 = 3.02$, the percentage of dry matter on cane going into the crystallizer massecuite; 3.02 $\div .94 = 3.21$, the massecuite per cent cane. Massecuite of 94° Brix weighs 94.4 lbs. per cubic foot, therefore 3.21 $\div 94.4 = 0.034$ cubic feet massecuite per 100 lbs. cane, or 0.68 cubic foot per ton of cane. Massecuite swells considerably, owing to the crystallization of its sugar and the decomposition of certain salts (see page 98) and it should also be diluted from time to time (see page 95). An increase of volume of 25 per cent is safe allowance for alteration, or $0.68 + 25$ per cent $= 0.85$ cubic feet. Further, the massecuite should remain in the crystallizer about four days, the time depending upon the size and type of the crystallizer, so we then have $0.85 \times 4 = 3.4$ cubic feet per ton of cane daily milling capacity. If the milling capacity is 1850 tons of cane the crystallizer capacity should be $3.4 \times 1850 = 6290$ cubic feet. The size of the crystallizers will depend upon the size of the vacuum-pans and under the usual con-

ditions with pans of 12 feet in diameter striking 1000 cubic feet, would be approximately $1000 + 25$ per cent $= 1250$ cubic feet; $6290 \div 1250 = 5 +$, the required number of crystallizers to actually hold the massecuite. Allowance must also be made for one empty crystallizer to receive massecuite and one to be discharging to the centrifugals, or in all 7 crystallizers of about 1250 cubic feet gross capacity each.

This estimate is based upon juice of exceptionally high purity. In actual practice the estimates should be upon the juice of the lowest purity that is liable to prevail over an extended period at any time of the manufacturing season. The lower the initial purity, the larger will be the quantity of crystallizer massecuite. In actual estimates the true solids and purity should be used to avoid errors.

211. Mixed Massecuites. Proportion of Molasses and Sirup.—These massecuites should be boiled to a definite purity, depending upon that desired in the molasses to be obtained from them. This formula assumes that the densities of sirup and molasses are the same. This is sufficiently accurate for practical purposes:

(A) Let $100 =$ total weight of massecuite in the strike;
$\qquad P =$ purity of the sirup;
$\qquad p =$ purity of the molasses to be boiled-in;
$\qquad M =$ purity of the required massecuite;
$\qquad x =$ percentage by weight of the strike to be formed of molasses;
$100 - x =$ percentage by weight of the strike to be derived from sirup,

then
$$x = \frac{100(P - M)}{P - p}.$$

This formula may be applied with less accuracy when P is the purity of a footing or nucleus upon which a strike is to be completed with molasses.

(B) This calculation may be made with greater facility by Cobenze's [1] method for mixtures, illustrated in the dia-

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[1] A. Cobense, Compendium der prakt. Photografic., 9th ed., p. 379; Van Nostrand's Chemical Annual, 1913, p. 563.

gram and example, Fig. 89. Let 85 be the coefficient
of purity of a sirup and 55 that of a molasses and let it be
required to make a massecuite of these having a purity of 65.
Arrange the numbers as in the diagram. Sub-
tract the purity number for the massecuite
from that of the sirup and the number for
the molasses from that of the massecuite and
arrange the remainders as shown in the dia-
gram; the remainder, 10, is the number of
parts of sirup required and 20 that of the
molasses. If the percentage of each constituent is required,
divide the number of parts of each by the total number of
parts, and multiply by 100. As in the previous method,
using purities only in calculating the mixture, it must
be assumed that the densities of the solutions are the same.
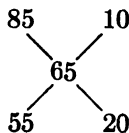
Fig. 89.

This method may be used for all mixtures and facilitates
the solution of many otherwise complicated problems. If
any three numbers used in the diagram are given the other
two are readily ascertained.

**212. Calculation of Added Water in Double
Filter-pressing of Scums (Cachaza).**—This is a prob-
lem in dilution and may readily be solved by the formula in
207 for dilution in terms of the normal juice. Let B of the
formula represent the solids in the first press-cake, b, the
solids in the reduced cake, and x, the percentage of added
water, then $x = 100(B-b)/b$.

The following example will illustrate the calculation:

A press-cake contained 35.06 per cent dry matter and after
reduction with water to a cream this contained 14.24 per cent
dry matter:

$$x = 100(B-b)/b = 100(35.06 - 14.24)/14.24 = 146.2 \text{ per cent.}$$

**213. Volume of Juice at a Given Temperature to
Weight at $17\frac{1}{2}°$ C.**—A sugar solution does not expand
on heating at the same rate as water (see Gerlach's table,
page 454). The expansion also varies with the sugar con-
tent of the solution. For the usual purposes the table of
Gerlach may be used, but the following method gives prac-
tically the same results and is more convenient. Note the

temperature of measurement; reduce the degree Brix of the juice to that at the temperature of measurement by means of Gerlach's table of corrections, page 489. Apply the specific gravity number corresponding to this reduced Brix to the weight of the cubic foot or gallon of water at the temperature of measurement.

Example: Required the weight of a cubic foot of juice of 15° Brix at 17.5°/17.5° C. measured at 28° C.

Degree Brix of the juice at 17.5° C. . . . . 15.0°
Hydrometer correction (page 489) for 15° Brix at
    28° C. 7

Degree Brix and corresponding specific gravity at
    28° C. . . . . (Sp. Gr. = 1.05831) 14.3°

Referring to the table on page 449, a cubic foot of water measured at 28° C. weighs 62.1289 lbs., therefore 62.1289 ×1.05831 = 65.75 lbs., the weight of juice required. The error of this simple method is well within the limits of accuracy of tank measurements. It is preferable that all measurements be made at, as nearly as is practicable, the temperature of graduation of the hydrometers, thus keeping all errors at a minimum.

214. Calculations Based upon the Relation between the Ash and Sucrose, etc.—These methods are used in ascertaining whether sugar or other matters are destroyed or decomposed and removed in a boiling process, for example. The mineral constituents of the materials are assumed to remain unchanged during the process, therefore a comparison of the saline coefficients (**181**) should show whether sucrose has been destroyed, and similarly whether other constituents have been decomposed. A method of this class must be used with great caution, since very slight inaccuracy of analysis or loss of mineral matter may lead to an erroneous conclusion. The true or Clerget number should be used in sucrose comparisons.

Example (all sucrose numbers are by the Clerget method): A clarified juice containing 15 per cent sucrose, 0.3 per cent ash and 50 saline coefficient was evaporated to sirup contain-

ing 50.7 per cent sucrose, 1.02 per cent ash and a saline coefficient of 49.71. The reduction of the saline coefficient by $50 - 40.71 = 0.29$, indicates decomposition of sucrose. This loss in percentage terms of the sucrose in the juice is calculated by finding what per cent 0.29, the decrease in the saline coefficient, is of the original coefficient 50, in this case 0.58.

This method has long been used in beet- and cane-sugar manufacture in estimating losses, but its application is somewhat limited by the fact of the deposition of a part of the ash constituents on the evaporating surface and in the storage tanks. C. H. A. Zimmermann [1] proposes to utilize only the soluble sulphates of the sulphated ash in this method, since the salts from which they are formed persist through the manufacture. The material is ashed as usual with the addition of sulphuric acid. The ash is transferred to an ashless filter or an alundum filtering-crucible and the soluble matter is removed by washing with hot water. The residue is dried and weighed. The difference between the original weight of ash and this residue is the weight of the soluble sulphates. The calculations are made as before.

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[1] Int. Sugar J., **16**, (1014), 383, also this work p. 336.

EVAPORATING AND JUICE HEATING.

DISCUSSION OF METHODS. METHODS OF CALCULATION.

BY

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215. General Considerations.—*Evaporation of Water.*
—At the low pressures used in sugar house work the tables
based on Regnault's formula

$$H = 1091.7 + 0.305(T - 32) \text{B.t.u., or}$$
$$H = 605.4 + 0.305\,T \text{ calories,}$$

are too inaccurate for use. Only tables such as Table A,
page 377 should be used.

216. Boiling Point of Sugar Solutions.—It is usual
to assume that the temperature at which any portion of a
given mass of water will boil is that corresponding to the
pressure on the surface of the entire liquid mass. In sugar
solutions this assumption leads to serious inaccuracies as
the temperature of boiling of a portion of a mass of sugar
solution will depend upon its density, its viscosity and the
absolute pressure on the surface of the portion considered.
This pressure will be that on the surface of the entire mass
increased by the pressure due to the depth of the portion
considered below the liquid's surface.

**217a. Variation of Temperature with Density and
Purity.**—The variation in the boiling-point of sugar solu-
tions with density is indicated in Gerlach's table, page 454.
In general, the variation is as in the following table:

	Degree Brix	20	30	40	50	60
Add	Degree Fahrenheit	1.1	1.8	2.7	3.6	5.4
	Degree Centigrade	.6	1.0	1.5	2.0	3.0

217b. The boiling point of sugar solutions is also influ-
enced by their purity.

218. Effect of Viscosity.—In the raw juice we some-
times have gums, mucilages and other compounds which
increase the viscosity of the fluid. As anything which

350

impedes the escape of the steam bubble from the heating surface tends to produce a local rise of temperature, it is easy to see that gummy sirups will have a higher temperature of boiling than pure sugar solutions. The difference is uncertain.

219. Variation with Depth Below the Surface.— At the low pressures used in sugar house work small differences in pressure produce far larger temperature differences than under high pressures. For example: What will be the temperature at which a small portion of sirup of 50.6° Brix will boil if it is under a head of 2 feet of solid (no bubbles) sirup in the third effect if the vacuum is 26 inches?

A head of 2 feet of sirup of specific gravity 1.236 (50.6°) will change the pressure of 2 pounds per square inch, corresponding to 26 inches of vacuum to 3.4 pounds per square inch. At 26 inches vacuum, water boils at 125.5° F.; under 3.4 pounds per square inch, or 23.8 inches of vacuum, it boils at 141.8° F. Add for density 4° F. and we have a temperature of 145.8° F. required to produce boiling in the sugar solution, without considering at all the effects of viscosity.

As transfer of heat from the heating to the heated liquid depends upon difference of temperature, we see that in this case there is a loss of $145.8 - 125 = 20.3°$ F., difference in temperature as compared to a similar condition in the case of water. We shall call these *lost degrees in temperature* and later will discuss their effect.

220. Specific Heat of Sugar Solutions.—The relation between the density of a sugar solution and its specific heat is expressed by the equation of a straight line and hence intermediate values to those below may be readily found:

Degree Brix of solution....	10	20	30	40	50	60	70	80	90
Specific heat..	.93	.86	.79	.72	.65	.58	.51	.44	.37

221. Heat of the Liquid.—To raise W pounds of a sugar solution whose specific heat is C, from a mean temperature, t_1, to a mean temperature, t_2, requires

$$WC(t_2 - t_1) \text{ B.t.u.}$$

Thus, to raise 10 pounds of sirup at 60° Brix from a mean temperature, 160° F., to a mean temperature, 180° F., would require $10 \times .58(180 - 160) = 116$ B.t.u.

222. To Heat Sugar Solutions and Evaporate Water.—The temperature of the vapor rising from a boiling sugar solution will be the same as that from pure boiling water under the same pressure. When the superheated bubble reaches the surface of a boiling sirup it loses all excess heat and temperature in vaporizing its watery envelope.

To raise W_1 pounds of juice from a mean temperature, t_1, to a mean temperature, t_2, and evaporate W_2 pounds of water at a temperature, t_3, corresponding to the pressure at the surface, requires $W_1C(t_2 - t_1) + W_2L_3$, where L_3 is the latent heat of water corresponding to t_3.

In cases where t_1 is greater than t_2, the quantity $W_1C(t_2 - t_1)$ is negative and must be subtracted.

223. Condensate.—In condensing steam in evaporators in sugar work, it is usual to assume that the condensate is removed at the boiling point. If taken to another place of less pressure it will tend to self-evaporation and will give up a number of thermal units equal to the loss in temperature in the condensate multiplied by its weight. Thus, if W pound of steam is condensed at t_1, it will give up WL_1 thermal units in its own vessel, and if the condensate is led to another vessel where steam is condensing at a lower temperature, t_2, it will there give up $W(t_1 - t_2)$ B.t.u.

224. Amount of Liquid to be Heated.—The amount of normal cane juice must be increased by the amount of maceration water, milk of lime, wash-waters, and the water used in diluting the defecator-bottoms (mud or cachaza). There is a removal of water by evaporation in the various tanks and with the filter-press cake. In careful experiments, it is usual to calculate the weight of the purified juice to be evaporated or heated from that of the raw juice, taking into consideration the dilution as indicated by the densities. The dilution of the juice varies with the milling methods and the manufacture; also, with the equipment of the factory. The total weight of liquid to be heated or concentrated usually ranges from about 90 to 110 per

cent of the weight of the cane. The mean evaporation in the multiple effect in tropical factories approximates 78 per cent by weight.

225. Heat Losses.—Heat is not only lost from the heating vessel itself by radiation but is lost from the pipes conveying heated liquid. Steam condenses in steam-pipes even when idle. The loss of heat is not negligible when the heating or evaporating is carelessly conducted.

226. Coefficient of Heat Transfer (K).—The unit of heat transfer, called the Specific Thermal Conductivity, is the number of thermal units transferred per hour from the steam through the heating surface to the sugar solution for each degree difference of temperature, Fahrenheit, between the steam and the solution for each square foot of heating surface.

The formulas for heat transfer are simple, but they all involve this unit which may have any value between 1500 B.t.u. and 50 B.t.u. per hour. Experience and judgment are required to select a proper value. Some of the variables effecting the value of this unit are:

(1) The velocity of the steam past the heating surface;

(2) The velocity of the sugar solution past the heating surface;

(3) The presence of air or other incondensible gases;

(4) The character and thickness of the deposits on either or both sides of the heating surfaces;

(5) The surface pressure and the depth, density and composition of the sugar solution being boiled.

The transfer of heat is the transfer of vibration and anything deadening the vibration results in loss. Steam molecules which have struck the surface and lowered their vibration rate should be swept aside to allow the impact of new molecules. On the sugar solution side of the heating surface, steam bubbles must be moved or swept away from the heating surface, as steam is a poor heat conductor. There is no longer any doubt as to the existence and enormous importance of surface films of gases, where the heating fluid is a gas, or of a vapor having air-containing films, as in condensers or effects, which magnify incalculably the resistance to the transfer of heat through the metal plate. Smith

found that at 90° F. the presence of air producing a pressure of 1/20 in. mercury reduced the heat transmission 25 per cent, and 3/20 in. mercury reduced it 50 per cent. Orrok [1] says that heat transmission varies with the velocity of the water in the tube to the 6/10 power and with $\left(\dfrac{P_s}{P_t}\right)$, where P_s represents the partial steam pressure and P_t the sum of the partial steam and air pressures. See "Vacuum Pumps," **246.** In the steam belt shown in Fig. 93, any air in the heating steam is positively forced to the outlet for incondensible gases.

High current velocity then is desirable on both sides of the heating surface. To secure high steam velocity the cross-section of the steam current at right angles to its path should decrease as rapidly as the volume of the steam is decreased by condensation.

Economy is increased by securing a positive fluid circulation in a predetermined path. In the ordinary standard effect there is no definite path of either the steam or the juice. The juice circulation is erratic. In some spots the transfer of heat is high, with a tendency to cause the juice to spout into the steam space, but the largest part of the heating surface is not used efficiently. In the steam heating space there are large volumes in which the incondensible gases accumulate and lower the efficiency by blanketing the heating surfaces. As the steam is eddying with cyclonic velocity, these volumes are constantly changing position. Eddy currents indicate inefficiency.

When exhaust steam is used for heating purposes, it is liable to contain much oil from the engines. The presence of this oil and of scale, arising from the lime used in the defecation, impede the transfer of heat.

As the metal used to separate the heated and heating fluids is generally either copper or brass and quite thin, the coefficient of heat transfer is not affected appreciably by its thickness.

227. Evaporation of the Juice and Crystallization of the Sugar.—Sugar juices are evaporated to the saturation or crystallization point in two distinct stages. The first

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[1] "Proportioning of Surface Condensers," G. A. Orrok, Transactions of the American Society of Mechanical Engineers, 1917.
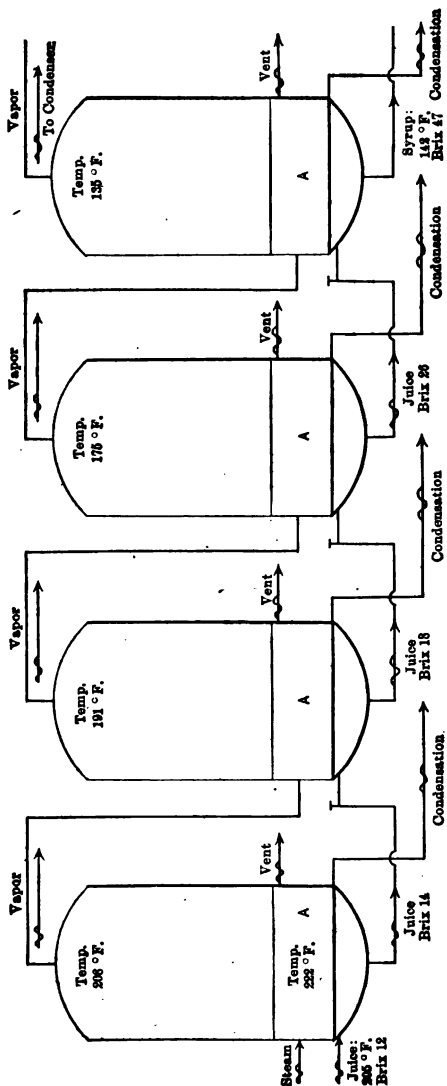
Fig. 90.

operation is practically continuous while the second involves a cycle of operations repeated several times daily. If a unit of 10 cubic feet of juice of about 12.5° Brix is sent to a series of vessels called a multiple effect, it will be evaporated therein to about 2 cubic feet. This thickened juice is called sirup and its density is about 53° Brix. It is pumped from the multiple effect and is stored in tanks, preparatory to the next operation. In the second stage our unit of two cubic feet of sirup will be drawn into a vacuum pan and evaporated to about 1 cubic foot of massecuite which will be about half sugar and half molasses. Besides evaporating water from the sirup to bring it to the saturation point, the operations in the pan include graining or forming the sugar crystals and the subsequent enlargement of the crystals to commercial size. This
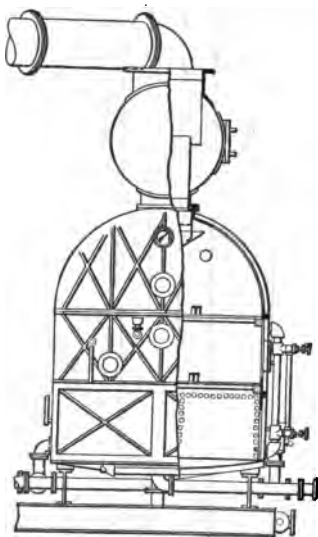
FIG.91.

operation is called boiling to grain. Efficiency of evaporation governs the design of the multiple effect, while vacuum pan design is more dependent upon efficiently handling and discharging a thick viscous mass quickly.

228. Multiple Effects.—In Louisiana the multiple effect usually consists of two or three vessels; in Cuba three or usually four are used ordinarily; while in Europe five and even six have been used. Properly operated, efficiency increases with the number of vessels in so far as fuel costs are concerned. These vessels are simple steam heaters where the condensing of steam on one side of a tube affords the heat necessary to evaporate water from the juice on the other side. Necessarily the temperature and pressure of

the steam on the heating side are higher than those on the juice or heated side. The vapor arising from the boiling juice in the first effect or vessel passes through a pipe to the steam space of the second effect, Fig. 91, and will evaporate water from the juice if the pressure maintained on this juice allows a proper fall of temperature between the two sides of the heating surface. The vapor arising in each effect does evaporative duty in the following one, except that from the last which is sent to a condenser.

In Fig. 90 the steam belt (A) could be of the form shown in section in Fig. 92. In this type the steam surrounds the small tubes. The juice boils up through the tubes and descends either through adjacent tubes or through the large down-take in the center. The large down-take may be omitted and several larger tubes used as down-takes as desired.

Note the following conditions in Fig. 90:

Effect................	I	II	III	IV
Temperature differences	14°	17°	16°	40°
Pressures:				
Steam side..........	3.2 lb.	− 2.3 in.	−10.5 in.	−16.2 in.
Juice side..........	−2.3 in.	−10.5 in.	−16.2 in.	−24.7 in.
Differences.........	8.7 in.	8.2 in.	5.7 in.	8.5 in.
Densities, Brix:				
Entering effects = 12°				
In effects...........	14°	18°	26°	47°

These data were obtained on test [1] and do not indicate either maximum capacity or maximum economy necessarily.

229. Disposal of Condensate.—The condensate in the steam belt of the first effect is free of sugar and may be used as boiler feed water. The condensate from the other effects, especially in the older types of evaporators, is liable to contain sugar carried over by entrainment in the rapidly moving steam from the preceding effect. There is rarely entrainment in modern well-proportioned and well-operated multiple effects. If the condensates containing even traces of sugar were used in the boilers, these would ultimately start foaming. In the modern factory, in which the con-

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[1] Figs. 90 to 93 are from a paper by E. W. Kerr in Transactions of the American Society of Mechanical Engineers, 1916.

densates contain no sugar, this water is used in feeding the boilers, in saturating the bagasse, in diluting tank-bottoms (mud or cachaza) and in washing the various tanks. The condensate from the second effect may be passed into the third and the total into the fourth effect and then be removed by means of a pump. It is usual to pump the condensate separately from each calandria, as the heating section or belt of the effect is often termed.

FIG. 92.

230. Disposal of Gases. — Incondensible gases are brought into the multiple effect in the steam or juice and are given off under the reduced pressures and tend to accumulate, unless removed as fast as they enter. Certain nitrogenous bodies of the juice decompose and form ammonia during the heating. The path of the heating steam should be positive so that the gases are forced to move continuously to the exit where they are removed by the pipes which connect each calandria with the condenser, or air pump for the purpose. In the case of the vacuum pans using high pressure steam, the air is removed by valves in connection with the steam traps. The steam traps let water pass, but neither air nor steam. The air relief valve will let the air escape but not the steam. Advantage is taken of the fact that air cools readily and will sink below the steam. After the air has escaped, the steam, in attempting to follow, heats a valve stem and so closes the valve that allowed air to escape.
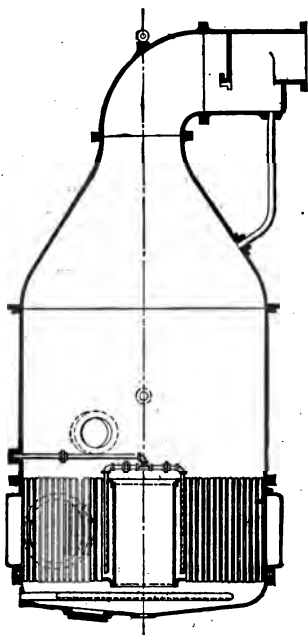
231. Juice Height.—In the ordinary standard vertical multiple effect, Fig. 92, the greatest capacity is secured when the juice height, as indicated by the glass gage exterior to the effect, is one-third to one-fourth the tube height. Inside the effect the steam bubbles may carry the juice over the tube sheet, but this does not indicate the juice level. The sirup is kept at the same height in all effects by hand-controlled valves or automatically, the amount pumped from the last effect being gaged by the amount of thin juice drawn into the first.

232. Different Types of Multiple Effects.—There are many different styles of multiple effects made of different modifications of the same few elements. The most common fault is too large juice capacity, so that the juice remains too long in the effect. Some types lack in the positiveness of the circulation of the steam or juice or in the withdrawal of the incondensible gases.

The heating surface is made up of straight tubes usually either vertical

Fig. 93.

or horizontal. Usually the steam passes through the horizontal tubes and the juice through the vertical ones. In one well-known type the juice is sprayed over inclined tubes containing steam. To permit air to escape the closed upper end of the tube contains a pin hole.

233. Tubes.—In the vertical standard effect the tubes are about $\frac{1}{16}$ inch thick, $1\frac{3}{4}$ inches or 2 inches in diameter and 40 to 54 inches long. The longer these tubes and the more intensely a small number of them is heated the more
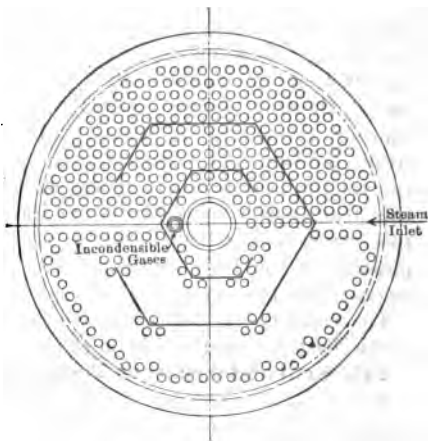
certain will they spout juice high up in the rapidly moving steam. The more efficient the heating surface, the more uniform will be the boiling over the entire top sheet and the smaller will be the temperature difference between the juice and steam sides. Intense localized heating should be avoided.

The tubes in horizontal effects are ¾ inch or 1 inch in diameter and about 12 or 14 feet long. Longer tubes are liable to sway unless supported in the middle. These tubes are generally arranged in nests of eight, which may be removed as a unit (Fig. 91).

234. Relations of Effects to Each Other.—Multiple effects will operate when they are not operating efficiently. All the steam arising in one effect must be condensed in the next steam belt following, and conditions will change so that this will occur. Suppose that the third effect suddenly had its heating surface covered with scale. It could not transmit the amount of heat it transmitted before, so the steam pressure and temperature in its steam belt would rise till the heat transmitted was sufficient to condense all the steam now coming over from the second effect. But this would be less than formerly, as the rise in the steam pressure in the belt or calandria of the third effect has increased the pressure on the juice side of the second effect.

The capacity of each effect depends upon the capacity of the effect preceding it and on the one following.

235. Real and Apparent Temperature Differences.—The difference between the temperature in the steam calandria of the first effect and the temperature of the vapor going to the condenser from the last effect is the total *apparent* range of temperature. For a single effect, such as a vacuum pan, this total range occurs in one vessel. In the double effect this range is divided into two parts, in a triple effect into three parts and in a quadruple effect into four parts. For the causes enumerated in a preceding paragraph, there are lost-degrees of temperature. These are tabulated below for a triple and quadruple effect, of the standard type, for usual conditions under three heads.

(1) The boiling temperature loss is due to the fact that

we are dealing with a sugar solution rather than with dis-
tilled water (217);

(2) The static head loss takes in the loss due to the depth
of the boiling liquid (216), (219).

(3) The third includes loss (assumed) due to the den-
sity and viscosity of the solution (218).

*To Obtain the Pressures to be Carried in the Vessels of the
Multiple Effect.*—In the table below, the total loss degrees
of temperature are 5.4°+9°+15.4°=29.8° F. The steam is
assumed to enter the first vessel at 227.2° F. and the vapor
to leave the last vessel at 125.4° F. The apparent range is
227.2°−125.4° and the real range is 227.2°−125.4°−29.8°
=72° F. This real range can now be divided, for a triple
effect, into three parts in accordance with conditions affecting,
the heat coefficients that have been considered as for instance
expected scale or oil on the heating surfaces. In the table
the ranges of 22°, 24° and 26° have been assumed. The
apparent range in each vessel is the sum of the assumed
real range in it and its expected lost degrees of temperature.
To obtain the temperature of the vapor rising in the first
vessel, subtract the apparent range in temperature, 27.4°
F., from the assumed steam temperature in the first steam
belt. The 199.8° F. so obtained is the steam temperature
in the second belt. Subtracting 33° F. from 199.8° gives
166.8° F., the temperature of the vapor in the second vessel.
From the steam tables (page 377) we can readily find the
pressures corresponding to the temperatures.

DISTRIBUTION IN A TRIPLE EFFECT.

	5-lb. Pressure.	26-in. Vacuum.	
Bodies.	1	2	3
Boiling temp. loss, F°	0.9	1.5	5.4
Static head loss, F°.............	1.5	2	3
Viscosity loss, F°...............	3	5.5	7
Total losses, F°.................	5.4	9	15.4
Assumed effective temp. dif., F°...	22	24	26
Apparent temp. dif., F°..........	27.4	33	41.4
Temperatures F°, 227.2..........	199.8	166.8	125.4
Pressure and vacua........+5 lb.	−6.4 in.	−18.5 in.	−26 in.

DISTRIBUTION IN A QUADRUPLE EFFECT.

Bodies.	1	2	3	4
Boiling temp. loss.....	0.9	1	1.5	5.4
Static head loss.......	1.5	1.7	2	3
Viscosity loss........	2.1	4.5	5.5	6.9
Total loss...........	4.5	7.2	9	15.3
Effective temp. dif., F°.	16	16	18	18
Apparent temp. dif., F°	20.5	23.2	27	33.3
Temperatures,F°, 227.2	206.7	183.5	156	125.2
Pressure & vacua + 5 lb.	−3.4 in.	−13.4 in.	−21.2 in.	−26 in.

In "Steam Economy in the Sugar Factory," Abraham, translated by Bayle, the following table is given, illustrating losses in temperature in evaporators of beet sugar factories:

LOSS IN TEMPERATURE, DIFFERENCE IN DEGREES FAHRENHEIT.

Evaporation System.	Individual Bodies.					
	I	II	III	IV	V	Total.
Single effect............	15.3	....	....	....	....	15.3
Double effect...........	7.2	15.3	....	....	....	22.5
Triple effect............	5.4	9	15.3	....	....	29.7
Quadruple effect........	4.5	7.2	9	15.3	....	36
Quintuple effect........	4.5	5.4	8.1	10.8	15.3	44.1

Hausbrand [1] gives even greater differences in the fall of temperature in the effects when the heating surfaces are of equal area. The ratios of the fall of temperature given by him are as follows:

In the double effect.....1   1.58

In the triple effect......1   1.44   3.44

In the quadruple effect..1   1.105   1.48   2.175

Applying these ratios in the preceding cases would give apparent temperature differences as follows:

	° F.	° F.	° F.	° F.
In the triple effect.......	17.3	24.9	59	
In the quadruple effect...	17.7	19.5	26.2	38.4

The discussion of the difference between real and apparent differences of temperatures has been introduced largely to

[1] "Evaporating, Condensing and Cooling Apparatus," E. Hausbrand, Eng. Ed., 113.

show why the heat transfer coefficient varies in the effects when apparent temperature differences are used.

236. Transfer of Heat.—The number of B.t.u. transferred from the heating to the heated side per hour is $KA(t_2-t_1)$ where $K=$ the mean thermal coefficient of conductivity per hour for the case considered; $A=$ the area in square feet; $(t^2-t^1)=$ the difference of the mean temperatures of the steam and juice. The value of K depends upon whether (t^2-t^1) is the difference of the apparent mean or real mean temperatures.

Tables B and C, pages 378–381, taken from a paper on "The Capacity and Economy of Multiple Evaporators," by E. W. Kerr in the *Transactions of the American Society of Mechanical Engineers*, 1916, contain much useful information. Thus in experiment No. 27, Table B, the total range of temperature is $14.5(1+1.14+1.10+2.76)=87°$ F. The heat transfer coefficients are for the apparent temperature difference in the effects; the average is

$464\times1+408\times1.14+448\times1.10+193\times2.76\div$
$$(1+1.14+1.10+2.76)=325 \text{ B.t.u.}$$

The radical difference in the coefficient of heat transmission in the first three effects and the last one is due in part only to the greater number of lost degrees of temperature in the last effect. It is interesting to examine the coefficients given in Table 248. For equal cleanliness of surface and equally good circulation the coefficients should decrease in increasing amounts from the first to the fourth effect.

In this experiment, 837,836 pounds of water were evaporated in 7.13 hours with a total temperature range of 87° F., and a mean apparent coefficient of heat transfer of 325 B.t.u. Assuming roughly that it takes 970 B.t.u. to evaporate one pound of water, we find the area of the heating surface, A, in one effect from the equation

$$325\times87\times A = 970\times837,836\div7.13,$$
$$A = 4000 \text{ sq. ft., approximately.}$$

Care must be taken to evaluate all parts of the table in any test. Thus, test No. 35 gives 5.3 pounds of water evaporated per hour per square foot of heating surface. But the steam pressure in the first steam belt was 8.7 pounds below the atmospheric pressure. Evidently the heat in this test was transferred so readily that the steam pressure

did not build up and if enough steam had been supplied to bring the pressure up to 18 pounds per square inch, absolute, the evaporation rate per square foot would have been enormously increased. In this test the total range of temperature was 53.8° F., that in the first effect being 7.6° F.

The original papers by Prof. Kerr should be consulted before drawing conclusions as to the relative efficiency of the evaporators included in his tests. The results of his tests are given in the tables at the end of this chapter, to serve as examples.

237. Heat Balance.—In properly operated clean effects it is close enough to say that 1 pound weight of steam per unit of time will evaporate approximately 3 pounds of water from 4 pounds of juice in a triple effect and that it will evaporate 4 pounds of water from 5 pounds of juice in a quadruple effect in the same unit of time. To show this, let us assume the steam temperatures on page 361 for a triple effect and also that the density of the entering juice is 12° Brix, the temperature being 180° F.

HEAT DISTRIBUTION IN A TRIPLE EFFECT.

	First Effect.	Heat.	Juice, lb.
1 lb. steam, 5 lbs. pressure per sq. in.	Latent = 960.7 B.t.u.		4.000

Heat required to raise 4 lb. juice at
  180° F. to 199.8° F., specific heat = 0.9,
  = (199.8 − 180) × 4 × 0.91 = ...   72

Total heat liberated............   888.7

Latent heat at 199.8° = 977.7 B.t.u.

Evaporation No. 1 = 888.7 ÷ 977.7 = ...909

Juice transferred to No. 2 effect..................   3.091

$$\frac{12}{Brix} = \frac{3.091}{4.00}. \quad \therefore \ Brix = 15.5°.$$

Second Effect.

Heat liberated as follows:
  Vapor from No. 1 effect................   888.7
Sensible heat from condensate:
  (227.2 − 199.8) × 1 = ...   27.4
Sensible heat from juice:
  (199.8 − 166.8)3.091 × 0.85 = ...   86.7

Total heat liberated......................   1002.8

Juice transferred to No. 2 effect...............	3.091
Latent heat at 166.8 = 998	
Evaporation No. 2 = 1002.8 ÷ 998 = ...	1.005
Juice transferred to No. 3 effect............	2.086

$$\frac{15.5}{\text{Brix}} = \frac{2.086}{3.091}. \quad \therefore \quad \text{Brix} = 23°.$$

Third Effect.

Vapor from No. 2 effect..................	1002.8
Sensible heat from condensate:	
(199.8 − 166.8)(0.909 + 1.005) = ...	63.2
Sensible heat from the juice:	
(166.8 − 125.4)(2.086)(0.75) = ...,....	64.7
Total heat liberated......................	1130.7
Latent heat at 125° F. = 1021	

$$\text{Evaporation in No. } 3 = \frac{1130.7}{1021} = ...$$

	1.107
	0.979

$$\text{Sirup from No. 3, } \frac{23}{\text{Brix}} = \frac{0.979}{2.086}. \quad \therefore \quad \text{Brix} = 49.$$

238. Increasing Evaporative Efficiency.—Theoretically it is always advisable on the score of steam economy to use low-pressure steam to heat low-temperature solutions and high-temperature steam to heat those of high temperature. By using a series of heaters taking steam at different temperatures, solutions can be raised to high temperatures in a series of operations.

Thus, all the heat in the steam going to the condenser from the last effect is wasted, yet a portion of that heat could be used to raise cold juices to within some ten degrees of its own temperature. In other heaters, steam taken from the vapor pipes of the third, second, or first effect could raise the juice to higher temperatures.

The practical objections to the scheme are the increased complexity of the apparatus, its initial cost and upkeep.

Let us make the following assumptions:

(1) The number of heat units in 1 pound weight of steam is the same at all pressures (practically).

(2) If x pounds of water are evaporated from a multiple effect, then the number of pounds of exhaust steam required will be x/n, if n is the number of vessels in the effect.

(3) If h pounds of steam are taken from the boilers and

used in any single effect heater, such as the vacuum pan or defectator, the steam used will be $\frac{x}{n}+h$.

Suppose that the steam being sent from the last effect to the condenser were of high enough grade, it is evident that we could save 100 per cent of h pounds of steam by diverting h pounds of this steam from the condenser.

Every pound of steam sent to the double effect should evaporate 2 pounds of water, but if 1 pound of vapor is removed from the vapor pipe leading to the second effect, then the evaporation has been reduced 50 per cent, as only 1 pound of water has been evaporated. By removing h pounds from the vapor pipe of the first effect we must send to the first effect $\frac{x}{2}+\frac{h}{2}$ pounds of steam, thus saving $\frac{h}{2}$ pounds.

Every pound of steam sent to a triple effect should evaporate 3 pounds of water. By taking off a pound of vapor

GAIN IN PER CENT BY ROBBING EFFECTS.

Evaporating system.	Steam Taken from Effect No. —				
	1	2	3	4	5
Single...................	100				
Double..................	50	100			
Triple...................	33⅓	66⅔	100		
Quadruple..............	25	50	75	100	
Quintuple..............	20	40	60	80	100

from the first effect we lose the evaporation of 2 pounds of water in the following effects and so the gain is 33⅓ per cent. If the vapor were taken from the vapor pipe of the second effect we evaporate 2 out of 3 pounds of water or gain 66⅔ per cent.

239. General Equations.—If we are to abstract h pounds of steam from only the first of n vessels and must evaporate x pounds of water in those vessels, we must furnish the first vessel with

(a) $\left(\dfrac{x}{n}-\dfrac{h_1}{n}\right)+h_1$ pounds of steam.

This expression may be considered to consist of two factors. We may imagine a weight of steam $\left(\dfrac{x}{n}-\dfrac{h_1}{n}\right)$ to act normally in n vessels and so evaporate $n\left(\dfrac{x}{n}-\dfrac{h_1}{n}\right)=x-h_1$

pounds of water. The other factor, h_1, evaporated the nec-
essary h_1 pounds of water from the first effect and this vapor
is sent to perform the auxiliary heating.

If h_2 pounds of steam are taken from only the second of
n vessels, the amount of steam that must be sent to the first
vessel will be

(b) $$\left(\frac{x}{n}-\frac{2h_2}{n}\right)+h_2.$$

As before, we may imagine the steam represented by
$\left(\frac{x}{n}-\frac{2h_2}{n}\right)$ to act normally and supply n times its value
in evaporation, or $(x-2h_2)$ pounds. The additional h_2
pounds of steam will evaporate h_2 pounds from *each* of
two effects, giving x for the total evaporation and h_2 for
auxiliary heating.

In general let h_1, h_2, h_3, . . . h_n pounds of steam be drawn
from the first, second, third, . . . nth effect, then the total
consumption of steam will be, on rearranging expressions
(a) and (b) above

$$\frac{x}{n}+h_1+h_2+h_3+. . .+h_n-\frac{(h_1+2h_2+3h_3+. . .+nh_n)}{n}.$$

240. Saving in Per Cent.—The saving h, may also be
expressed as a percentage of x, so that the consumption of
steam and the saving may be expressed in terms of x.

Thus, if $h_1 \div x = p_1$, $h_2 \div x = p_2$ . . . $h_n \div x = p_n$, the con-
sumption of steam expressed as a percentage of that required
for direct multiple effect evaporation would be

$$\frac{100}{n}+p_1+p_2 . . . p_n-\frac{(p_1+2p_2+3p_3 . . . np_n)}{n},$$

and the percentage saving would be

$$(p_1+2p_2+3p_3 . . . np_n)\div n.$$

In a quadruple effect the first effect is robbed of $0.15x$,
the second effect of $0.10x$ and the third of $0.05x$, the saving is

$$(.15\times.25+.10\times.50+.05\times.75)x=\frac{12.5}{100}x \text{ or } 12.5\%. \text{ (238.)}$$

or $$(.15+2\times.10+3\times.05)\div4=12.5\%.$$

In a quadruple effect if, in one instance, the first, second
and third effects are robbed of equal amounts of steam,

and, in another instance, the second effect is alone robbed of the same quantity of steam, the efficiency is the same in both cases theoretically:

$$\frac{.25 + .50 + .75}{3} = .50.$$

Practically, however, the reduction in complexity of piping makes the robbing of the second effect preferable.

241. Pauly Heaters or Pre-evaporators.—When the supply of exhaust steam from the various engines is not sufficient there is a choice between admitting live steam direct from the boilers into the steam belt of the first effect or of using this live steam in a heater and sending the resulting vapor into the steam belt. If P pounds of steam are sent to the preheater, it will deliver P pounds of steam to the first effect, and care must be taken not to count this steam twice. The multiple effect proper must now evaporate $x - P$ pounds of steam, and this will require either

$$\frac{x-P}{n} + h_1 + h_2 + \ldots h_n - \frac{(h_1 + 2h_2 + 3h_3 + \ldots nh_n)}{n}$$

or

$$\frac{x-P}{n} \text{ pounds of steam,}$$

according as the effects are robbed or not.

If the effects are robbed, then the first effect must receive

$$\left\{ \frac{x}{n} - \frac{(n+1)P}{n} + h_1 + h_2 + \ldots h_n - \frac{(h_1 + 2h_2 + 3h_3 + \ldots nh_n)}{n} \right\} + P,$$

which we shall call for simplicity $\Sigma E + P$ pounds of exhaust steam, ΣE being the quantity enclosed by the brackets.

If the effects are not robbed, the first effect will receive $\left(\frac{x-P}{n} - P \right)$ pounds of exhaust steam, and P pounds from the preheater or a total of $\left(\frac{x-P}{n} \right)$ pounds.

The total amount of boiler and exhaust steam to supply the various auxiliary machines and the effects when the former use H_a, H_b, H_c . . . H_g pounds of steam and the effects are robbed of h_1, h_2, h_3 . . . h_n pounds of steam will be

$$\Sigma E + P + H_a + H_b + \ldots H_g - (h_1 + h_2 + \ldots h_n) =$$
$$\frac{x}{n} + H_a + H_b + \ldots H_g - \frac{P}{n} - \frac{(h_1 + 2h_2 + 3h_3 + \ldots nh_n)}{n}.$$

242. Steam Consumption in a Cane Sugar House.

In the manufacture of cane sugar most factories do not use preheaters nor do they rob the effects, though the large use of maceration water and the high cost of fuel is leading to the rapid introduction of preheaters and preevaporators. The preevaporator is also used to increase the evaporative capacity of the factory. In beet sugar factories preevaporators are generally used and the effects are robbed of vapor.

In the following example the weight of steam used for any purpose is expressed as a percentage of the weight of the cane ground. It is further assumed that there is no difference in the quantity of heat in a pound of high-pressure steam and in that of a pound of low-pressure steam; that a pound of steam in condensing will evaporate a pound of water from the juice; that a preheater may be used and that a vacuum pan using low-pressure steam for heating is feasible.

In a house provided with a quadruple effect, the evaporation is 78 per cent of the cane weight and the exhaust steam supplied the first effect is therefore 78/4 per cent. The vacuum pans use 22 per cent and for heating 16 per cent steam is used. The weight of steam used is then, for,

(1) Straight evaporation, no preheater, no robbing of effects,

$$\frac{78}{4} + 16 + 22 = 57.5\%.$$

(2) If a preheater receiving 10 per cent steam is used,

$$\frac{(78-10)}{4} + 16 + 22 = 55\%.$$

(3) If a preheater receiving 10 per cent steam is used and the first effect is robbed of 10 per cent steam for a low-pressure vacuum pan, the second effect is robbed of 10 per cent for juice heating and the fourth effect is robbed of 6 per cent for heating purposes,

$$\frac{(78-10)}{4} + 10 + 6 + 22 - \frac{10 \times 1 + 10 \times 2 + 6 \times 4}{4} = 41.5\%.$$

If the effects are not robbed it is usual to give each vessel the same heating surface. This cannot be done if the effects are to be robbed as the mass of steam sent from one effect to the next diminishes greatly. Thus,

The exhaust steam sent to the first effect $= \Sigma E =$

$$\frac{78}{4} - \frac{5 \times 10}{4} + 10 + 10 + 6 - \left(\frac{10 \times 1 + 10 \times 2 + 6 \times 4}{4}\right) = 19.5\%.$$

$\Sigma E \ldots 19.5$

Steam from pre-heater } 10.0- -29.5%—I—19.5%—II—9.5%—III—9.5%—IV—3.5%.

10%   10%   6%

10%   29.5%   19.5%   9.5%   9.5%

Evaporation 78%
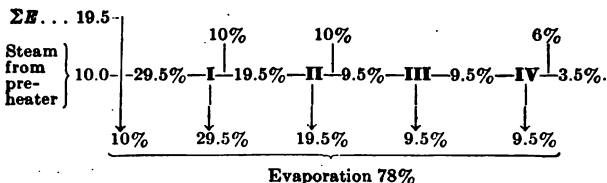
Where a factory is prosperous, it is usual to increase its capacity. If changes are to be made in the sizes of effects, it is well to consider "robbing," letting the old effects follow a new first effect, enlarged to provide the necessary extra heating surface.

243. Heating Surfaces.—By referring to Table B, page 378, one is struck by the wide disparity in temperature fall allowed in the different effects in different houses, and also by the disparity in the coefficients of thermal conductivity in the different effects in houses of the same capacity.

It is evident that the results obtained when the effects are new and free of oil and incrustation, and are operated with the proper fall of temperature in each vessel, will be different when these economic conditions do not obtain.

Under average conditions, for example, we may assume that a quadruple effect will evaporate 6.5 to 7.5 pounds of water per square foot of heating surface per hour and hence we can obtain the heating surface necessary by dividing the water to be evaporated in each effect per hour by 6.5 to 7 5.

Thus, if a quadruple effect is to evaporate 100,000 pounds of water per hour, the heating surface of each effect will be

$$100,000 \div (6.5 \times 4) = 4000 \text{ sq. ft., approximately.}$$

If the effects are robbed of vapor, the area of the heating surface of any effect is found by multiplying the weight of cane ground per hour by the product of the percentage of evaporation in that effect and the latent heat of the steam and dividing by the product of the apparent fall of temperature in that effect and its assumed coefficient of heat

transmission in thermal units per hour. In the case of the first effect, the numerator of the fraction indicated should be increased by the quantity of heat in thermal units required to heat the juice from the temperature at which it enters the first effect to the temperature of boiling in that effect. The latent heat may often be assumed at 1000 thermal units for convenience.

The amount of evaporation in the first is to that in the fourth effect as 29.5 is to 9.5. (*See* diagram, page 370.) The steam sent to the condenser is only 3.5 per cent, thus reducing the quantity of injection water and air-pump capacity required.

Thus, suppose in case (3) above that the weight of juice = the weight of the cane (owing to the dilution by maceration water) is 125,000 pounds per hour; that it enters the effect at a temperature of 200° F. and is boiled at 213° F. Let the apparent temperature falls in a quadruple effect be 15° F., 17° F., 20° F., and 40° F., the corresponding coefficients of heat transmission be 450 B.t.u., 420 B.t.u., 400 B.t.u., and 200 B.t.u., and the latent heat be equal to 1000 B.t.u., approximately:

Heating surface of first effect

$$= \frac{125,000(0.9(213-200)+0.295\times1000)}{15\times450} = 5680 \text{ sq.ft.}$$

Heating surface of second effect

$$= \frac{125,000(0.195\times1000)}{17\times420} = 3414 \text{ sq ft.}$$

Heating surface of third effect

$$= \frac{125,000(0.095\times1000)}{20\times400} = 1484 \text{ sq. ft.}$$

Heating surface of fourth effect

$$= \frac{125,000(0.095\times1000)}{40\times200} = 1484 \text{ sq. ft.}$$

It is somewhat cheaper to make the effects of the same dimensions. This is also advisable under the usual operating conditions, in which the heating surfaces of the vessels containing the concentrated juice are more or less coated with scale. Evidently the dimensions of the third and fourth effects may be increased by diminishing the allowed

fall of temperature in them and those in the first two decreased by increasing correspondingly the fall of temperature in them.

EXAMPLE: Find the area of the heating surface of a juice heater for a factory of 1000 tons of cane, daily grinding capacity; steam equal to 6 per cent of the weight of the cane to be taken from the vapor pipes of the second effect at a temperature of 183.5° F., the weight of the juice is that of the cane and its temperature entering the heater is 100° F., assumed coefficient of heat transfer is 250 B.t.u. per degree Fahrenheit difference between the two sides. Assume the steam to lose 1000 B.t.u. per pound and that the specific heat of the juice is 0.9.   The rise in temperature in the juice

$$= \frac{1000 \times 2000 \times 0.06 \times 1000 \text{ B.t.u.}}{1000 \times 2000 \times 0.9} = 66.6° \text{ F.}$$

The mean difference of temperature between juice and steam sides of the heater

$$= 183.5 - \left(\frac{100 + 100 + 66.6}{2}\right) = 50.2° \text{ F.}$$

Allowing 10 per cent for radiation and other losses, the heating surface will be

$$1.1 \times \frac{1000 \times 2000 \times 0.9 \times 66.6}{250 \times 24 \times 50.2} = 438 \text{ sq. ft.}$$

The original juice temperature plus its rise in temperature must be ten or more degrees below the assumed steam temperature.

244. Vacuum Pan.—A vacuum pan is a single effect, evaporating from 12 to 15 per cent of the quantity of water, required to be evaporated by the multiple effect.   Economy of time rather than economy of steam is sought in its design. To boil and drop a strike quickly is desired.   To boil quickly there are required properly clarified sirup, good sirup circulation, steam coils free of condensate and air and as great difference in temperature between the heating steam and the massecuite as is practicable.   To drop a strike quickly the heating surfaces must not impede the free fall of the massecuite.

Boiler steam, passing a reducing valve, is admitted to a vertical manifold having 6 or 8 branches or nozzles entering the pan. Inside the pan these nozzles divide into 2 or 4 helical 4-inch copper tubes preferably not longer than 40 feet. In large pans there may be two manifolds on opposite sides of a diameter having similar nozzles and tubes. These tubes must be so arranged as to give the best circulation and the quickest drop possible.

No tube must contain steam unless it is covered with massecuite. In the first part of the operation the mass in the pan is rather thin and diminishes in volume till it is ready to form grain. After that period during the building up of grain the mass increases in density and amount to a maximum when the pan is full. Owing to lost degrees in temperature in boiling deep masses of massecuite, high-pressure steam, 45 pounds per square inch, is usually used. Sugar is often boiled with exhaust steam. When this steam enters a tube at high velocity, as it does in the first part of the process, when the sirup is thin, and condenses, considerable unbalanced pressure results that sets up excessive vibration, unless the tube is restrained by collars fastened to rigid uprights. The soft coils must not rub against their collars and produce pin holes in the tube.

In designing the pan, about 0.55 boiler horsepower or 450 pounds of steam must be allowed per ton of cane per day.

245. Condenser.—By condensing the steam from the last effect or vacuum pan the pressure is reduced below that of the atmosphere. As the steam is accompanied by air and other incondensible gases, either dissolved in the original juices or sirup, or formed during the heating process or through leakage, an air pump must be provided to remove them so that the vacuum may be maintained. The barometric condenser is a preferred type on plantations. It is a condenser placed at a height above the ground so that it may discharge by gravity against the atmospheric pressure when the bottom of its discharge pipe is submerged in an open tank filled with water.

In the modern type the vapor pipe from the effect or pan enters the condenser at the side near the bottom and as

the suction pipe of the air pump is attached at the top, the path of the gases is toward the top. The injection water enters near the top of the condenser and is broken up into sprays or thin sheets through which the vapors must pass on their way to the air pump opening. As the vapor and water move in opposite directions, it is sometimes called a counter-current condenser.

The discharge pipe usually supports the condenser. It should be about 34 feet high. To find the minimum height in feet, divide the difference between the absolute pressure of the atmosphere and the minimum absolute pressure to be carried in the condenser in pounds per square inch, by the weight of a column of the discharge water 1 foot high and 1 square inch in cross-section. To this add the height of water in feet necessary to produce the assumed velocity of efflux of the discharge water.

Fins or projections should be placed on the bottom cone of the condenser proper to prevent the water from whirling and so rising above the normal level.

Example.—If 5 cubic feet of discharge water per second, weighing 60 pounds per cubic foot, are to be discharged from a discharge pipe of 0.5 square foot cross-section from a condenser carrying a pressure of 2 pounds, absolute, into the atmosphere at a pressure of 14.7 pounds per square inch, the minimum height will be found as follows:

$$(14.7-2) \div \frac{60}{144} = 30.5 \text{ ft.;}$$

$$V^2 = 2gh; \quad \therefore \quad h = \frac{100}{64} = 1.56 \text{ ft.;}$$

$$\text{Minimum height} = 30.5 + 1.56 = 32.06 \text{ ft.}$$

246. Vacuum Pump.—Cast iron is porous and air will leak through it, although it may be tight with regard to steam or sirup. A vacuum should be raised and the entire surfaces of effects and pans should be heated gently and then painted with a paraffine or other paint which will close these pores. Joints of all descriptions may leak air. The length of time a vessel will hold a vacuum indicates its

air tightness. Air leakage may be two or more times the amount of air that must be handled unavoidably.

The office of the air pump is to pump air and other incondensible gases rather than vapor. The air and vapor come off as a mixture so that pumping some vapor is unavoidable, but this can be reduced to a very small amount if the air is cooled to a temperature not exceeding that of the incoming injection water by more than 10° or 15° Fahrenheit. To do this bring the vapor, just as it is entering the suction opening of the air pump, into contact with surfaces having the temperature of the incoming injection water.

The pressure in the condenser is nearly the same in all parts but the temperatures of the different parts of the vapor mass may differ considerably. If we take the temperature of the vapor and from the tables find the corresponding pressure we shall find this pressure less than that actually existing in the condenser. The difference of these pressures is the pressure due to the incondensible gases. The lower we cool the vapor the less the amount of steam in any given mass and the greater the amount of air as the total pressure remains constant. The proportion of vapor and of air present is in proportion to the pressures they exert. This is Dalton's law of mixed gases.

Thus suppose that the absolute pressure in a condenser as shown by the gauge was 102 mm., and that a thermometer shows that the temperature of the vapors was 50° C. From the table we see that the pressure corresponding to this temperature is 92.3 mm., that is, $\frac{P_s}{P_i} = \frac{92.3}{102}$. The air pressure is $102 - 92.3 = 9.7$ mm. At the top of the condenser let this vapor meet cooling surfaces at 15° C. and acquire a temperature of say 20° C. By the table we see that the steam pressure is now 17.5 mm., and, since the total pressure in the condenser is 102 mm., the air pressure is $102 - 17.5 = 84.5$ mm. Each stroke of the air pump would remove $\frac{84.5}{9.7}$ $= 8.6$ times as much air as it would have removed under the previous conditions.

The work of the air pumps can be enormously reduced by

(1) Reducing air leakage;

(2) Using no more injection water than necessary;

(3) Reducing the temperature of the vapors going to the air pump to a minimum.

(4) Using pumps with no clearance volume.

Example.—Suppose 1000 kilograms of steam are sent to the condenser per hour and lose 600 calories (roughly) per kilo. Temperature of injection water is 15° C.; temperature of discharge water 43° C.; barometer 760 mm.; absolute pressure in the condenser is 102 mm.; temperature of vapor at orifice to air·pump suction pipe is 20° C. As the amount of air in the sirup is small, it having been heated in clarification, and as the condensate from the first effect is used for boiler feed, we will assume in effects or vacuum pans that the injection water carries all the air into the condenser except air leakage. The latter will be assumed in this case equal to the amount of air carried in by the injection water. Assume that the volume of air at atmospheric pressure and at $(273°+15°)=288°$ C., absolute, is 5 per cent of the volume of the water and that the efficiency of the air pump is 80 per cent. Find the volume of air pump displacement per minute:

One kilo steam requires $600 \div (43-15) =21$ kilos injection water.

Each kilo of injection water contains 0.05 liter air at 760 mm. and 288° C., absolute. At 84.5 mm. and 293° C. this becomes 0.46 liter by applying equations

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \quad \text{or} \quad \frac{760 \times 0.05}{288} = \frac{84.5}{293} V_2.$$

Displacement volume of air pump per minute is

$$\frac{(21 \times 1000 \times 0.46)2 \times 100}{60 \times 80} = 402 \text{ liters.}$$

The effect of increased leakage or higher temperature of gases passing into the condenser is readily calculated.

247. TABLE A.—PROPERTIES OF SATURATED STEAM AT DIFFERENT VACUA AND PRESSURES.

Vacuum.	Temp. F.	Cu. Ft. per Pound.	Latent Heat. B.t.u.
28.0 in.	101.15	339.6	1035
27.5	108.70	275.2	1030
27.0	115.06	231.9	1027
26.5	120.55	200.2	1024
26.0	125.38	176.7	1021
25.5	129.75	158.1	1019
25	133.77	143.0	1017
24	140.64	129.0	1013
23	146.78	104.5	1009
22	152.16	92.3	1006
21	157.00	82.6	1003
20	161.42	74.8	1001
19	165.42	68.5	998
18	169.14	63.1	996
17	172.63	58.6	994
16	175.93	54.5	992
15	179.03	51.2	990
14	181.92	49.0	989
13	184.68	45.5	987
12	187.31	43.2	985
11	189.83	41.1	984
10	192.23	39.21	983
9	194.52	37.4	981
8	196.73	35.8	980
7	198.87	34.3	978
6	200.94	33.0	977
5	202.92	31.8	976
4	204.85	30.6	975
3	206.71	29.5	974
2	208.52	28.6	973
1	210.28	27.7	972
0	212.00	26.8	970
1 lb.	215.3	25.2	968
2	218.5	23.8	965
3	221.5	22.5	964
4	224.4	21.4	962
5	227.2	20.4	961
6	229.8	19.5	959
7	232.4	18.6	957
8	234.8	17.8	955
9	237.1	17.1	954
10	239.4	16.5	953

248.   TABLE B, PART I.—PRINCIPAL DATA FROM TESTS OF SUGAR HOUSE EVAPORATORS (E. W. KERR).

DESCRIPTION OF THE EVAPORATORS.

Number.	Type (1).	Number of Bodies.	Rated Capacity, Gals. per 24 Hrs. 75% Evaporation.	Length of Tubes, Feet.	Diameter of Tubes, Inches.	Heating Surfaces of Each Body in Sq. Ft.	Method of Removing Condensation. See Footnote.*	Method of Venting. (See Footnotes.)*	Number of Days Since Cleaned.
1	A	4	290,000	4.5	2	4504.8	f	bc	6
2	A	3	270,000	4	2	3740	....	.....	3
3	A	3	290,000	4	2	3983	e	None	3
4	A	3	185,000	4	2	2579	e	bd	0
5	A	3	280,000	4	2	....	e	Note 1	0
6	A	3	210,000	4	2	2855	e	None	7
14	B	4	145,000	9.5	¾	2000	Note 2	d	6
15	B	4	145,000	9.5	¾	2000	Note 2	d	3.5
16	B	4	145,000	9.5	¾	2000	Note 2	d	7
17	B	4	250,000	13	⅞	3432	e	c	0
18	B	4	250,000	13	⅞	3432	e	c	0
23	C	4	400,000	7.25	4.5	2570	g	Spec.	0
24	C	4	400,000	7.25	4.5	2570	g	Spec.	0
25	C	4	400,000	7.25	4.5	2410	g	Spec.	0
27	D	4	400,000	....	...	4000	f	Note 3	3
28	D	4	400,000	....	...	4000	f	Note 3	2
29	D	4	400,000	....	...	4000	f	Note 3	0
30	D	3	200,000	23	...	2112	f	None	0
33	E	3	220,000	4	2	3054	f	Note 4	1
34	E	3	......	4	2	2683	f	Note 4	2
35	E	3	......	4	2	2683	f	Note 4	7
38	G	4	290,000	4	2	1529	e	h	3

*a, through shell at side; b, through top tube sheet; c, direct to condenser; d, body to body; e, pumps each body; f, syphon body to body; g, barometric leg pipe; h, each tube vented.

Note 1. Vented through 12 holes $\frac{1}{16}''$ each, direct to vapor space.

Note 2. Centrifugal pumps each body.

Note 3. 2″ vents at side, bottom, and top, body to body.

Note 4. See Fig. 92.

(1) A ="Standard," vertical submerged tubes; B = Jelinek; C = Lillie; D =Kestner; E =Webber's "Standard"; G =Sanborn.

248. TABLE B, PART II.—PRINCIPAL DATA FROM TESTS OF SUGAR HOUSE EVAPORATORS (E. W. KERR.)

(REFER TO PART I FOR DESCRIPTIONS OF EVAPORATORS)

Number.	Duration of Test, Hours.	Type.	Number of Bodies.	Steam Pressure. First Body, Lbs. Abs.	Steam Pressure. Last Body, Ins. Abs.	Temp. Deg. Fahr. Entering Juice	Temp. Deg. Fahr. Leaving Juice	Density, Deg. Brix at 17.5°C. Entering Juice	Density, Deg. Brix at 17.5°C. Leaving Juice	Evaporation, Per Cent. By Weight	Evaporation, Per Cent. By Volume	Juice Treated per 24 Hrs., Equiv. to 75% Evaporation, Per cent Rated Capacity.	Water Evaporated, Lbs.	Water Evapo-rated per Lb. of Steam Supplied, Lbs.	Water Evapo-rated per Hr., rated per sq. ft. Heating Surface, Lbs.	Thermal Efficiency, per cent.
1	7.13	A	4	16.3	1.8	183.5	101	13.7	50.2	72.7	76.6	137	587,914		5.44	85.06
2	6.66	A	3	14.6	3.6	185.9	134.2	15.2	55.5	72.6	77		350,584		5.19	89.05
3	6	A	3	15.3	3.4	188.6		13.2	58.2	72.4	78.6	102	505,304		6.35	
4	12.75	A	3	15.6	3.4	198.4		15.4	61.1	74.7	79.4	138	933,684		10.38	90.48
5	5.33	A	3	16.7	3.9	183.8	124.5	13.2		72.2	77.4	83	327,466		4.96	
6	4	B	4	14.7	3.5	194	119.8	13.3	58.2	72.6	81.3	87	195,763		5.27	
14	4	B	4	22.9	3.1	200.7	129.2	18.5	55.9	67.6	72.5	109	155,198	3.52	4.85	
15	4	B	4	21.4	3.8	199.2	127.3	16	62.9	62.9	62.9	174	248,701	3.7	5.77	
16	6	B	4	23.7	4.0	200.5		13	47.2	66.1	70.3	107	225,586	.3	4.69	
17	4.5	C	4	18.7	3.7	181	140	13	57.5	78.1	82.1	86	314,062	3.4	5.18	
18	6	C	4	17.4	5.9	196.5	141	13.2	59.3	77.5	79.9	116	319,833	.3	5.08	
23		C	4	19.1	6.5	194	144	12.7	53.2	77.7	81.9	94	556,923	3.71	9.02	96.9
24	6.06	D	4	17.7	6.0	191.8	131	11.6	58.7	80.5	84.6	94	553,877	3.95	8.98	97.5
25	7.13	D	4	17.9	4.5	188.8	141.8	12.6	65.3	71.8	78.7	76	450,293	3.69	8.71	97.5
27	6.03	D	4	17.9	4.9	205	136.9	12.8	47.3	72.7	76.1	138	837,836	4.21	7.34	94.8
28	6	D	4	18.1	5.2	207.7	132.6	16.5	46.2	64.3	68.5	124	748,958	4.24	7.76	93.6
29	4	E	3	14.8	2.3	208.8	125	16.9	45.4	75.4	78.8	131	790,172	4.28	8.23	86.5
30		E	3	14.6	4.6	212.2	136	15	46.2	70.6	74.8	93	191,585	2.91	6.27	97.4
33	5.39	E	3	11.06	5.2	171		14.7	58	73	75.2	105	338,859	2.49	4.4	
34	4	E	4	6.07	3.8	184.6	129.2	15	51	76.7	81.2		190,517		6.3	
35	5.69	G		15.4		179			50.8				156,176		5.95	
38						188.1	147.4		64.2				206,917			

248. TABLE B, PART III.—RELATIVE TEMPERATURE FALL AND COEFFICIENT OF HEAT TRANSMISSION.

(Data from Tests on Sugar House Evaporators, E. W. Kerr.)

No.	Temp. Fall, 1st Body. Deg. Fahr.	Relative Temperature Fall.				Coefficient of Heat Transmission.					No. of Days Since Cleaned.
		1st Body.	2d Body.	3d Body.	4th Body.	1st Body.	2d Body.	3d Body.	4th Body.	Average	
1	17.4	1.0	0.67	0.87	4.41	315	430	372	62	172	6
2	14.8	1.0	1.89	3.21	...	556	163	111	...	200	3
3	33.4	1.0	0.27	1.62	...	174	663	114	...	184	3
4	17.3	1.0	1.22	3.31	...	447	355	147	...	247	0
5	14.0	1.0	1.85	3.08	...	371	170	113	...	174	0
6	4.4	1.0	8.30	11.61	...	1185	126	107	...	166	7
14	18.9	1.0	0.69	1.85	2.87	239	270	97	79	130	6
15	21.1	1.0	0.52	1.22	2.50	321	508	203	90	202	3.5
16	19.2	1.0	0.66	1.88	2.24	192	344	115	113	154	7
17	17.0	1.0	0.95	1.26	2.45	220	202	161	87	146	0
23	15.0	1.0	0.80	0.93	2.93	545	648	600	207	394	0
24	14.0	1.0	0.95	1.07	2.52	610	593	552	286	449	0
25	11.6	1.0	1.02	1.27	4.62	680	644	505	143	334	0
27	14.5	1.0	1.14	1.10	2.76	464	408	448	193	325	3
28	15.2	1.0	1.11	1.14	2.60	444	405	426	209	328	2
29	18.0	1.0	0.67	1.01	2.17	397	605	378	244	353	0
30	16.1	1.0	1.50	4.14	...	402	287	107	...	192	...
33	19.8	1.0	0.75	2.01	...	317	393	152	...	244	1
34	5.0	1.0	3.29	6.38	...	769	219	130	...	217	2
35	7.6	1.0	1.18	4.91	...	623	558	149	...	284	7
38	8.0	1.0	1.13	1.88	5.38	682	571	365	138	293	3

249. TABLE C.—SUMMARY OF STEAM CONSUMPTION TESTS.[1]

	Condensation per Ton Cane.	Steam F and A 212° F. per Ton of Cane.	Equivalent Lbs. Steam at Boiler per Ton Cane.	Steam F and A 212° F. Per Cent on Cane.	Steam F and A 212° F. Per Cent of Total.	Boiler Horse-power per Ton of Cane.	Boiler Horse-power 4500 Tons Cane per 24 Hrs.
	Lbs.	Lbs.					
1 Evaporators	417.0	413.7	410.0	20.67	28.2	.4985	2242.3
2 Vacuum pans, "straight" strikes	191.4	192.7	191.0	9.63	13.17	.2323	1045.3
3 Vacuum pans, mixed strikes	164.2	164.87	163.4	8.24	11.02	.1887	849.2
4 Vacuum pans, crystallizer strikes	89.32	90.0	89.2	4.5	6.11	.1084	477.8
5 Vacuum pans, average	444.92	447.57	443.6	22.37	30.3	.5395	2427.7
6 Live steam heaters	81.5	81.4	80.7	4.07	5.52	.0977	439.6
7 Exhaust steam heaters	210.7	208.6	206.7	10.43	14.16	.2512	1130.4
8 Kestner heater	28.0	27.75	27.5	1.39	1.88	.0332	149.2
9 Equivalent of mechanical work	......	54.66	54.17	2.73	3.72	.0657	295.65
10 Total accounted for in factory	1182.12	1233.68	1222.67	61.67	83.7	1.4859	6686.5
11 Radiation and unaccounted for assumed	......	239.0	236.8	12.00	16.22	.2790	1246
12 Total delivered by boilers[2]	......	1479.68	1459.47	73.67	100.00	1.7649	7932.5

[1] By Prof. E. W. Kerr, Guanica, P. R.

[2] Based upon the assumed radiation and unaccounted for of 12 per cent.

PURCHASE OF CANE ON A BASIS OF ITS ANALYSIS.

250. General Considerations.—Cane is susually sold to the factories at a "flat" price, *i. e.*, its quality, as regards sucrose content and the purity of the juice, is not considered. A system of purchase on test would undoubtedly increase the profits of both the manufacturer and the grower. The grower would be forced to take better care of his fields and deliver the cane as soon as possible after cutting. Prompt delivery of the cane would result in increased delivery weight and sugar production with a decrease in costs to the manufacturer.

The problem of devising a system of purchase that will be not only equitable, but that may be operated without exciting the distrust of the farmer is not a simple one.

Sales are sometimes based upon the degree Brix of the juice, without regard to either the sucrose content or the coefficient of purity. This method forces the factory to pay a very conservative price for the cane, to offset the low purity of the juice in the early part of the season. This method has probably been used on account of the fairly good idea of density (Baumé) held by cane farmers in general.

The real difficulty in devising a system of purchase lies in the sampling of the cane itself. Small samples from a cart or car are usually of very little value in indicating the analysis of the cane and especially so when the juice for testing is expressed by a laboratory mill. The only method of sampling that has given practical results is that of the juice drawn from the factory mills and representing the entire load of cane. This method is included in the daily routine of many factories in comparing canes from the various fields and railway switches.

Given a representative sample of the juice from a particular lot of cane, the next step is the estimation of its sugar value to the manufacturer. This might be based upon the sucrose content of the cane, but the difficulty of determining this number is an objection. The method selected must be

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better than a rough approximation in order to protect the manufacturer and be fair to the farmer. Obviously, to be equitable, the method must be based upon a consideration of of the available sugar, and in figuring this number, the coefficient of purity of the juice and the efficiency of the factory must enter. The method described in the following paragraph, though apparently complicated, is in fact quite simple.

251. Available Sugar as a Basis of Cane Purchase. —A special chemist and assistants are required for these tests.

Reduction Factors.—The chemist should first determine two reduction factors, in cooperation with the chemist of the factory, as follows: (1) Factor for reducing the degree Brix of the juice from the crusher to that of the mixed normal juice of all the mills. (2) Factor similar to the preceding for reducing the per cent sucrose of the crusher-juice to that of the normal juice. The first factor has long been used and is regularly determined at intervals by the factory chemist (**168**). To determine these factors, operate the milling plant for a short period without saturation-water; sample and separately analyze the juice from the crusher and the mixed juice from the entire plant. Calculate the ratio or factors, (1) Brix of the normal mixed juice + Brix of the crusher-juice and (2), Sucrose per cent in normal juice + sucrose per cent crusher-juice.

Sampling.—The number of the cart or car of cane is noted and the chemist is given a ticket bearing this number and is advised to prepare for sampling. If cart cane is to be sampled, it is advisable to group a number of loads under one test. The chemist notes the position of the cane on the conductor or elevator, using markers if need be, and after the cane reaches the crusher he allows a definite interval for the expressed juice to wash the rolls and then preferably samples continuously and automatically or at brief intervals during the passage of the cane. The sample is sent to the laboratory with the ticket corresponding to it. Sample follows sample in this way.

Analysis.—On receipt of the samples by the laboratory, the samples and tickets are arranged in regular order. A numbered cylinder is filled to overflowing with the strained juice and the remainder of the sample is held in reserve

pending the completion of the test. The cylinders should be arranged in convenient groups, of ten, for example, and after the latest to arrive has been standing ten minutes the hydrometers are inserted. After a further interval of five minutes the degree Brix and temperatures are to be noted. The observed Brix, temperature and corrected Brix should be entered on a duplicate of the load ticket. These operations should be conducted very systematically, allowing a definite period for each.

The sucrose test should be made by Horne's dry lead method, page 234. The laboratory equipment should include a considerable number of 200 cc. (approximate) cylinders like *C* of Fig. 39. Each of these should have a mark etched on it to indicate approximately the 100 cc. point. A spoon having a conical bowl should be provided for measuring the dry lead. It should hold about 1 gram of lead, "struck" measurement.

Arrange a group of these cylinders, corresponding to those used for the density determination, and fill each to the mark with juice. Add a measure of lead to the juice, cover the cylinder with the palm of the hand and mix its contents by vigorous shaking. Filter, polarize and calculate the sucrose by Schmitz's table, page 468. Enter this test on the ticket.

Available Sugar.—Multiply the degree Brix by the corresponding reduction factor and the per cent sucrose by its factor. This gives the degree Brix and the per cent sucrose in terms of the normal juice. Calculate the coefficient of purity. The available sugar is now calculated by the method given on page 305, and this in turn to a basis of the factory by applying the efficiency and normal juice extraction-numbers. The following example indicates the steps in the calculation:

Example:

Factor for reducing the degree Brix........ 0.978
Factor for reducing the per cent sucrose.... 0.965
Degree Brix of the crusher-juice........... 18.0
Per cent sucrose in crusher-juice.......... 15.7
Assumed mill extraction, normal juice...... 78.0
Average efficiency number of the factory.... 98

Degree Brix of calculated nor-
mal juice............... $= 18.0 \times 0.978 = 17.60$
Per cent sucrose calculated
normal juice............ $= 15.7 \times 0.965 = 15.15$
Coefficient of purity calcu-
lated normal juice........ $= 15.15 + .1760 = 86.08$
Sucrose extracted by the mills
in normal juice.......... $= 15.15 \times .78 = 11.82\%$ cane

Referring to the second section of the table on page 515 we find 97.43, the yield number of 96° sugar corresponding to 86.1 purity. This number multiplied into the sucrose extracted gives the yield of sugar per cent cane on a basis of 100 factory efficiency, $11.82 \times 97.43 = 11.52$. Since the factory efficiency number is 98 we must reduce the yield figure accordingly: $11.52 \times 0.98 = 11.29$, the percentage yield of 96° sugar that may be expected from the cane.

The reliability of this method may be judged from the actual sugar-house results given on page 307.

This method enables the manufacturer to arrange a scale of prices based upon the actual yield of sugar that the cane may be expected to give in his factory.

ANALYSIS OF LIMESTONE, LIME, SULPHUR AND SULPHUROUS ACID.

ANALYSIS OF LIMESTONE.

252. Preparation of the Sample.—Fragments should be chipped from a large number of pieces of the stone and reduced to a uniform size, then mixed and sub-sampled by quartering. The small sample should be reduced to a very fine powder in an iron mortar or on a grinding-plate. Particles of metallic iron, from the mortar or plate, should be removed by stirring the powder with a magnet. Sift the powder through an 80-mesh sieve, and mix it thoroughly by sifting or otherwise.

253. Determination of Moisture.—Dry 2 grams of the powdered stone to constant weight in a tared flat dish or a watch-glass. The oven should be heated to 110° C. The loss of weight divided by 2 and multiplied by 100 is the percentage of moisture.

254. Determination of Sand, Clay, and Organic Matter.—Treat 1 gram of the powdered limestone in a beaker, with a few cubic centimeters of hydrochloric acid, being cautious, in adding the acid, to prevent the projection of particles of the material from the glass. Cover the beaker with a watch-glass and heat the liquid a few minutes. Collect the residue on a tared quantitative filter, wash it thoroughly with hot water, and reserve the filtrate (*A*) for further treatment. Dry the filter and residue to constant weight at 110° C. The weight of the residue multiplied by 100 is the percentage of sand, clay, and organic matter. Place the filter and residue in a tared platinum crucible and incinerate. The weight of this residue (*A*) multiplied by 100 is the percentage of sand and clay, *i.e.*, silica and combined silica and alumina. The difference between this percentage

and that obtained before incineration is the percentage of organic matter.

255. Determination of Soluble Silica.—Evaporate the filtrate (*A*) from the preceding determination to strict dryness, on the water-bath, using a platinum or porcelain dish. Moisten the residue with hydrochloric acid and again evaporate to dryness. It is advisable to continue the heat for an hour or longer after apparent dryness, to insure the insolubility of the silica. Treat the residue with dilute hydrochloric acid; collect the insoluble portion on a small quantitative filter and wash it thoroughly with hot water until free of chlorides. Reserve the filtrate (*B*) for further use. Partially dry the filter and contents, then insert them in a tared platinum crucible, and char the paper by the application of a very gentle heat. If charred too rapidly, there may be difficulty in subsequently burning off the carbon. Increase the heat until the filter is completely incinerated, and then raise it to bright redness; Cool the crucible and contents in a desiccator and weigh. The weight of the ash of good quantitative filters, or of the so-called "ashless filters," is so small that it need not be taken into account.

The weight of the residue, multiplied by 100, is the percentage of silica, SiO_2 in the soluble silicates of the stone.

256. Determination of Total Silica.—Mix the residue *A* (**254**), in the platinum crucible with four or five times its weight of [1] mixed carbonates of sodium and potassium and fuse at a red heat. Continue the heat about thirty minutes after the contents of the crucible are in a quiet state of fusion.

Remove the bulk of the mass from the crucible, while still warm, with a platinum wire, to facilitate the subsequent solution. Place the crucible and the material removed from it in a beaker and treat with dilute hydrochloric acid, being careful to avoid loss by the projection of the liquid from the glass. Use heat, if required. Wash and remove the crucible. Filter the solution and evaporate it to strict dryness, as described for soluble silica in the preceding para-

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[1] Use strictly chemically pure, dry carbonate of sodium and potassium, mixed in molecular proportions and finely powdered. The proportions are 106 parts sodium carbonate to 138 parts potassium carbonate.

graph. Treat the residue with dilute hydrochloric acid as before, wash it on a filter and reserve the filtrate (C). Incinerate the filter and heat the residue to bright redness, weigh, and calculate the percentage of silica as described in the preceding paragraph. Subtract the percentage of soluble from that of the total silica, to obtain the percentage of silica present as sand in insoluble silicates.

257. Determination of Iron and Alumina.—Combine filtrates A, B, and C from the preceding operations and concentrate them to a convenient volume. Add a slight excess of pure ammonia to the solution while it is still hot, boil it until only a slight odor of ammonia can be detected, collect the precipitate on a small filter, filtering rapidly while the solution is hot. If there is considerable iron and alumina present, it is advisable to dissolve the precipitate with dilute hydrochloric acid and reprecipitate it with ammonia as directed above, uniting the filtrates (D). Partly dry both filters, and incinerate as advised for silica. If ashless filters are used, no correction need be made for them.

The residue consists of the mixed oxides of iron and alumina (Fe_2O_3, Al_2O_3). Multiply the weight of the residue by 100 to obtain the percentage.

It is not usually necessary to determine the iron and alumina separately. If required, however, proceed as follows: Treat 1 gram of the powdered limestone with concentrated hydrochloric acid, most conveniently in a platinum dish. Evaporate to strict dryness, moisten with hydrochloric acid, and again dry on the water-bath, as described for the silica determination. Treat the residue with dilute hydrochloric acid, with heat, and filter; wash the filter with hot water and treat the filtrate with ammonia, as described above, to precipitate the iron and alumina. Wash the precipitate into a small dish, dissolve it in sulphuric acid, and evaporate the solution nearly to dryness. Wash the residue into an Erlenmeyer flask, being cautious in the use of the water.

The iron is now most conveniently determined by titration with a standardized solution of permanganate of potassium.

Add a small quantity of pure zinc-dust to the solution in the flask, to reduce the iron from the ferric to the ferrous state, and titrate with the decinormal permanganate solution. This solution is added until a faint permanent pink color is produced. Multiply the burette reading by .008 to ascertain the weight of ferric oxide in 1 gram of the stone, and this weight by 100 to obtain the percentage of ferric oxide (Fe_2O_3); subtract this per cent from the combined percentages of iron and alumina, to obtain the percentage of alumina.

258. Determination of Calcium.—To the filtrate from the iron and alumina determination (D), corresponding to 1 gram of the stone, add sufficient hydrochloric acid to render it slightly acid. Concentrate this solution to a convenient volume, neutralize it with ammonia, heat to boiling, and add an excess of boiling-hot oxalate of ammonium solution. Set aside for twelve hours, then collect the precipitate of oxalate of calcium on a quantitative filter, wash with cold water (filtrate E), dry and incinerate the filter in a tared platinum crucible, then ignite the residue strongly. The residue consists of almost pure calcium oxide (CaO), and may be weighed as such, or, more accurately, it may be converted into the sulphate ($CaSO_4$) or carbonate ($CaCO_3$), and weighed. It requires less time and labor to convert into the sulphate, using the following solution:

Add one volume of sulphuric acid to an equal volume of water, and neutralize three parts of strong ammonia with this acid, then add to it two parts of ammonia. Dissolve 2 grams of ammonium chloride in each 100 cc. of this solution. Filter the solution if necessary, and preserve it for use in calcium determinations. Strictly chemically pure reagents must be used in preparing this solution.

Add an excess of the ammonium sulphate solution, prepared as described, to the residue in the crucible, evaporate to dryness, ignite strongly, cool and weigh. The weight of the residue multiplied by .41158 gives the weight of calcium oxide (CaO), and by .73416 the weight of calcium carbonate ($CaCO_3$), in 1 gram of the stone, and these numbers multiplied by 100 give the percentages of calcium oxide (quicklime) and calcium carbonate respectively.

The residue may be converted directly into calcium carbonate, if preferred, as follows: Mix it with finely powdered ammonium carbonate, moisten it with water, heat it some time at a temperature between 50° and 80° C., to expel the ammonia, then below a red heat. Repeat this operation until a constant weight of carbonate of calcium is obtained. The weight of the carbonate of calcium multiplied by .56 gives the weight of calcium oxide in 1 gram of the stone, multiplied by 100 the product is the percentage of calcium oxide. The weight of calcium carbonate multiplied by 100 is the percentage of this substance.

259. Determination of Magnesium.—To the filtrate E, from the calcium determination, after concentration to approximately 100 cc., add a slight excess of ammonium hydrate, then add sodium phosphate solution in excess, drop by drop, with vigorous stirring, to precipitate the magnesium as a phosphate. After fifteen minutes add a decided excess of ammonia. Set aside during several hours, preferably over-night, to insure a complete precipitation. Collect the precipitate in a Gooch crucible, wash it with dilute ammonia, containing 1 part ammonia of 0.96 specific gravity, to 3 parts water. The washing should be continued until a drop of silver nitrate solution added to a drop of the filtrate, acidulated with nitric acid, produces at most only a faint opalescence. The precipitate is ammonium-magnesium phosphate; dry it, first at a gentle heat, then increase the temperature to expel the ammonia, and finally ignite it a few minutes in the flame of a blast-lamp to convert the residue into pyrophosphate of magnesium. Cool the residue in a desiccator and weigh it. The weight of the magnesium pyrophosphate ($Mg_2P_2O_7$) multiplied by .36208 gives the corresponding weight of magnesium oxide. The magnesium is present in limestone as carbonate. Multiply the weight of the pyrophosphate by .7574 and the product by 100 to ascertain the percentage of magnesium carbonate in the stone.

In limestones which contain very little magnesium, the method proposed by Prinsen-Geerligs and modified by Herzfeld [1] and Forster may be used. Dilute 2 grams of

[1] Zeit. Rübenzucker-Industrie, 1896.

the powdered stone with concentrated hydrochloric acid in a porcelain dish. Evaporate the solution to dryness on a hot-plate or sand-bath, then heat the dry matter over a naked flame, to render the silica insoluble. Treat the residue with hydrochloric acid, boil, add a few drops of nitric acid, and evaporate the solution to small bulk, to expel the greater part of the acid. Dilute the solution with water, and add an excess of calcium carbonate, to precipitate the iron and alumina and filter, using a flask to receive the filtrate, and wash the precipitate with hot water. Add lime-water in excess to the filtrate, mix, then fill the flask to almost the top of the neck with water. Stopper the flask and set it aside for the precipitate to settle, then decant the supernatant liquid through a filter, and wash the precipitate by decantation as before. Dissolve the precipitate, including any particles which may adhere to the filter, using hydrochloric acid. Precipitate the calcium from the solution, as described in **258,** with oxalate of ammonium, and remove it by filtration; precipitate the magnesium as ammonium-magnesium phosphate, and convert it into the pyrophosphate as already described.

260. Determination of Carbonic Acid.—It is not usually necessary to determine the carbonic acid, as it may be calculated from the quantity required to combine with the lime and magnesia, except when sulphates are present.

The gravimetric determination is made with one of the various forms of alkalimeters. Knorr's apparatus, Fig. 94, is one of the best of these. The method of using this apparatus is as follows: A weighed quantity, 5 grams or more, of the finely powdered limestone, is introduced into the flask A with 50 cc. or more of distilled water. The tube G is connected with a filter-pump to draw a current of air through the apparatus during the entire process. The bulb B contains the acid for decomposing the stone, preferably concentrated hydrochloric. The guard-tube C is filled with fragments of caustic soda, potash, or with soda-lime, to prevent the entrance of carbonic acid with the air. Open the stop-cock on the bulb-tube B and admit the acid slowly; the liberated gas passes through the con-

denser *D*, where most of the moisture is condensed, thence
through the bulbs *E*, containing concentrated sulphuric acid,
which removes every trace of water; the dry gas bubbles
through the tared bulbs *F*, containing a caustic potash solution
of 1.27 specific gravity, which absorbs the carbonic acid, and
the residual air, containing water from the potash solu-
tion, passes on through the guard-tube *F*, which absorbs
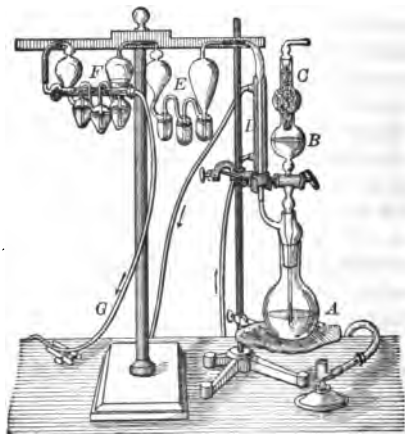
FIG. 94.

the moisture, and ecapes through *G* and the filter-pump.
The gas should flow at the rate of 4 to 5 bubbles per second.
When the bulb *B* is empty, heat the contents of the flask
carefully, finally boiling the liquid slowly, to expel the car-
bonic acid.   Air should be passed through the apparatus for
a few minutes after boiling, to insure the removal of all the
carbonic acid.   Caps should be placed over the inlet and
outlet tubes of *F* while making the weighings, to prevent the
absorption of carbonic acid or moisture.   When the operation
is completed, place the bulbs and guard-tubes *F* in the balance-
case, and after a few minutes weigh them.   The increase
in weight divided by the weight of material used and the
quotient multiplied by 100 is the percentage of carbonic acid.

A similar apparatus may be fitted up, using an ordinary flask, with cork connections and an empty U tube, as recommended by Gladding, instead of the condenser D.

In the determination of carbonic acid with Schroetter's or similar apparatus, proceed as follows: The description refers to Fig. 95. Fill the tube on the left, to above the upper bulb, with concentrated sulphuric acid, and that on the right with dilute hydrochloric acid. Weigh the flask and contents, then introduce approximately 1.5 to 2 grams of the powdered limestone, by the opening at the left, and weigh again. Lift the stopper on the hydrochloric-acid tube, and open the stop-cock and admit a little acid. In the decomposition of the stone, the carbonic acid is set free and bubbles through the sulphuric acid, which retains any watery vapor that would otherwise pass off with the gas. Repeat this operation from time to time until no more carbonic acid is disengaged. Heat gently to expel the carbonic acid from the solution, cool, and weigh. After cooling and wiping the apparatus, it should be placed inside the balance-case a few minutes before weighing. The loss in weight is that of the carbonic acid set free. Divide this weight by that of the limestone used and multiply the quotient by 100 to obtain the percentage of carbonic acid.
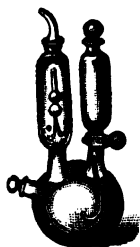
FIG. 95.

The carbonic acid in the limestone used in sugar manufacture is almost entirely combined with calcium; a small portion is sometimes in combination with magnesium. Occasionally the stone contains a vein of dolomite, a carbonate of calcium and magnesium.

In the absence of gypsum, sulphate of calcium, if either the percentages of calcium or magnesium and carbonic acid are given, the percentages of the two carbonates may be calculated: The percentage of calcium oxide $(CaO) \times 1.7857 =$ percentage of calcium carbonate $(CaCO_3)$; the percentage of carbonic acid in the magnesium carbonate $(MgCO_3)$ multiplied by 1.916 = the percentage of magnesium carbonate.

Example.—A sample of limestone contains 54.8 per cent calcium oxide and 43.4 per cent carbonic acid; required, the percentages of calcium and magnesium carbonates.

CALCULATION.

$54.8 \times 1.7875 = 97.96$, per cent calcium carbonate.

$97.96 - 54.8 = 43.16$, carbonic acid in the calcium carbonate.

$43.4 - 43.16 = 0.24$, carbonic acid in the magnesium carbonate.

$0.24 \times 1.916 = 0.46$, the per cent magnesium carbonate.

Many sugar-house chemists calculate the carbonates in this way, in order to economize time. In many cases this method will supply all the information necessary relative to the purity of the stone, but it is not usually advisable to depend entirely upon it. A serious objection to this process is the fact that there may be slight errors in the determinations of the calcium and carbonic acid which would lead to false deductions. It is advisable, as a rule, to determine both the bases and the acids.

261. Determination of Sulphuric Acid. — The limestone may contain small quantities of sulphate of calcium, which is calculated from the percentage of sulphuric acid. Digest 5 grams or more of the powdered limestone with hydrochloric acid, using heat. Dilute the solution, filter it, and wash the residue thoroughly with hot water. Concentrate the filtrate, in a beaker, to a volume of about 50 cc., heat it to boiling and add a solution of barium chloride, a few drops at a time, maintaining the boiling temperature. Remove the beaker from the lamp, after each addition of the chloride, to permit the barium sulphate to settle, and test the supernatant liquid for sulphuric acid. Continue the boiling of the solution and the additions of the reagent so long as a precipitate forms; set aside over night. Collect the precipitated barium sulphate in a tared Gooch crucible, wash it with hot water, heat it to redness, cool and weigh it. The weight of barium sulphate $\times .343 \div$ weight of limestone used $\times 100$ = percentage of sulphuric anhydride (SO_3); the weight of barium sulphate $\times .5833 \div$ weight of limestone used $\times 100$ = percentage of calcium sulphate.

262. Notes on the Analysis of Limestone. — It may be necessary in some of the determinations to use a larger portion of the stone than 1 gram. If so, it is convenient to

use a multiple of 1 gram, dissolve it and dilute the solution to a definite volume, 5 grams to 500 cc. for example, and use measured portions of this solution for the determinations.

A Gooch crucible will usually be found much more convenient for the filtrations and ignitions than filter-paper and an ordinary crucible. Alundum may be substituted for the filter or Gooch, except in determining total silica.

In these methods of analysis, only those determinations are given which are necessary in judging a limestone for sugar-house purposes.

Sundstrom [1] has suggested a method for the rapid analysis of a limestone, an abstract of which follows:

(a) Weigh two portions of 1 gram each of the finely powdered sample, transfer them to small dishes and add about 100 cc. of distilled water to each. To one portion add 25 cc. of normal hydrochloric acid (300), cover the dish with a watch-glass until all action ceases; heat the solution to boiling, cool and titrate it with normal sodium hydrate (304), using methyl orange as an indicator. The number of cc.'s of normal hydrochloric acid—the number of cc.'s of normal soda solution = cc.'s of normal hydrochloric acid required to saturate the carbonates of lime and magnesia.

(b) To the second portion of 1 gram, cautiously add 5 cc. of concentrated hydrochloric acid, keeping the dish covered to avoid loss. After all effervescence ceases, evaporate the material to complete dryness over a low flame. When dry, cool, take up with a little hot water and a few drops of hydrochloric acid; heat to boiling, filter through an ashless filter, washing all insoluble portions into the filter, and wash free of all traces of chlorides with boiling water.

(c) Dry the filter and contents; ignite in a tared platinum crucible to bright redness, cool under a desiccator and weigh for silica (SiO_2).

(d) Neutralize the filtrate and washings from (b) with ammonium hydrate, in slight excess; heat to boiling, collect the precipitate and wash free of chlorides. Dry and ignite the filter and contents; cool and weigh for oxides of iron and aluminum (Fe_2O_3 and Al_2O_3).

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[1] Journal of the Society of Chemical Industry, **16.** 520.

(e) Heat the filtrate and washings from (d) to boiling, add a concentrated solution of oxalate of ammonium, also heated to boiling. Allow the mixture to stand until clear, which, if the analysis has been rightly conducted, requires two or three minutes; decant the clear solution into a filter, dissolve the precipitate in hydrochloric acid and reprecipitate with ammonium hydrate. Allow to settle and decant as before, and then wash the whole precipitate into the filter and wash with hot water until free of chlorides and oxalates. Dry the filter and contents, ignite in a platinum crucible, at first cautiously, then over a blast-lamp, until the residue is converted into calcium oxide (CaO); cool under a desiccator, weigh and calculate the weight to terms of calcium carbonate ($CaCO_3$) as in the previous methods. Titrate the residue with normal hydrochloric acid as a check.

Divide the percentage of calcium carbonate by 5 (=cc. of normal hydrochloric acid required for calcium carbonate), subtract the quotient from the number of cubic centemeters of normal hydrochloric acid required for (a), and multiply the remainder by 4.2 to obtain the percentage of $MgCO_3$.

Sundstrom states that this method is very rapid and sufficiently accurate for technical purposes.

ANALYSIS OF LIME.

263. Determination of the Calcium Oxide in Lime. —Add sufficient water (30 cc. ca.) to 10 grams of lime, in a mortar, to form a thick milk. Add an excess of pure sucrose in the form of a solution of 35–40° Brix and mix it intimately with the lime, which forms a soluble saccharate. Transfer the solution and residue to a 100-cc. flask, using a sugar solution of the above compositon to wash the last portions from the mortar and to complete the volume to 100 cc.; mix and filter. Titrate 10 cc. of the filtrate with a normal solution of hydrochloric acid (**300**), using phenolphthalein or lacmoid as an indicator. The burette reading×.028 = the weight of calcium oxide (CaO) in 1 gram of the lime, and×100 = percentage of calcium oxide.

264. Determination of the Proportion of Un-

burned and Slaked Lime.—Slake 1 gram of lime with water, add an excess of normal sulphuric acid (302) and heat to expel carbonic acid if present; add a few drops of cochineal solution or other suitable indicator, and ascertain the excess of sulphuric acid used, by titration with normal sodium hydrate (304). Calculation: (cc. of normal sulphuric acid—cc. of normal soda solution)$\times$.028 = the total weight of calcium, as calcium oxide, in 1 gram of the lime, and $\times$ 100 = the percentage of total calcium as calcium oxide. This number—percentage of calcium oxide = percentage of unburned and slaked lime as calcium oxide.

265. Determination of Calcium Oxide, etc. Degener-Lunge Method.—Both the above determinations may be made with one titration, using phenacetoline as suggested by Degener and applied by Lunge.

Slake a weighed portion of the lime with water, add a few drops of phenacetoline solution and titrate with normal hydrochloric acid. Add the acid until the yellow color changes to a red, and read the burette. This reading multiplied by .028 gives the weight of calcium oxide. Continue the addition of the acid; the solution remains of a red color until all the calcium is saturated, then changes to a golden yellow. It is advisable to make this titration a few times for practice with material of known composition. The burette reading multiplied by .028 gives the total weight of calcium as calcium oxide. The unburned and slaked limes are determined by difference.

266. Complete Analysis.—The methods described for limestones may be applied for a further analysis of the lime if required.

<center>ANALYSIS OF SULPHUR AND SULPHUROUS ACID.</center>

267. Estimation of the Impurities.—Transfer 0.5 gram of the powdered sulphur to a flask provided with a well-fitted glass stopper. Add at one time an excess of saturated bromine-water and shake thoroughly. Water dissolves 2 to 3.25 per cent of bromine at ordinary temperatures, and, as at least 15 parts bromine are required for 1 part of sulphur, it is advisable to use from 275 to 400 cc. of the bromine water to insure sufficient of the reagent for the

oxidation of the sulphur to sulphuric acid. Boil the solution to expel the excess of bromine, collect the residue and wash with hot water; dry and weigh. A Gooch crucible is convenient for collecting the residue. The weight of the residue × 200 = percentage of impurities. The percentage of sulphur may be calculated directly from that of the sulphuric acid in the filtrate (261), or, with sufficient accuracy for practical purposes, by subtracting the percentage of impurities from 100.

Commercial roll-sulphur is usually very pure. Its quality can generally be satisfactorily determined from its color and relative freedom from dust and small fragments.

268. Estimation of Sulphuric Acid in Sulphurous Acids.—The following method is recommended by Herzfeld [1]: Pass the sulphurous acid gas into a 40 to 50 per cent sucrose solution for ten to twenty minutes. Test a portion of the solution for sulphuric acid by the addition of barium chloride and hydrochloric acid. An insoluble precipitate of barium sulphate forms in the presence of sulphuric acid. If a quantitative test is desired, a measured volume of the gas must be used and the precipitated sulphate must be collected in a Gooch filter and be washed with hot water, dried and ignited to redness. The weight of the barium sulphate × 0.343 = the weight of sulphuric anhydride (SO_3) in the volume of gas used.

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[1] Zeitschrift, 1911, 917; Int. Sugar Journ., 1912, **14**, 113.

LUBRICATING OILS.

269. Tests Applied to Lubricating Oils.—A few oil tests may be made in the sugar-house laboratory without expensive or special apparatus. Some of the methods given here, while not assuring the greatest accuracy, will generally answer for sugar-house purposes. The analysis usually includes the "cold test," viscosity, acidity or alkalinity and purity tests.

270. Cold Test.—Pour a portion of the oil, to the depth of approximately one and a half inches, into a test-tube one and three-eighths inches in diameter. Plunge the tube into a freezing mixture and stir with a thermometer until the paraffine begins to separate, or until the oil ceases to flow, on inclining the tube. Remove the tube from the mixture and hold it between the eye and the light and note the temperature at which the paraffine disappears. The oil must be stirred during the entire test. Repeat the test two or three times and record the mean of the two readings which agree best with one another, as the temperature of the cold test. With very dark oils, and with certain other oils, the beginning of the separation of the paraffine cannot be noted with accuracy, hence the reading is made at the temperature at which the oil ceases to flow.

271. Viscosity Test.—The viscosity test may be made with a flow-viscosimeter. Engler's viscosimeter is shown in Fig. 96. The inner or oil-chamber is arranged for accurately measuring the oil. This chamber is surrounded by a water-bath. A plug at the center closes the exit-tube. The apparatus is so arranged that the oil will flow through the exit-tube under the same conditions in comparative tests.

In making a test, the inner chamber is filled to the mark

with water at 20° C. or other standard temperature, and this temperature is maintained during the experiment by means of the water-bath. The plug is lifted and the time in seconds is noted that is required for 200 cc. of water to flow into the graduated flask. A stop-watch is used in timing the flow.

Fig. 96.

The inner chamber and the tube are next thoroughly dried and the chamber is filled with the oil. The temperature of the oil and bath are maintained at the standard temperature. The plug is again lifted and the time required for the flow of 200 cc. of oil is noted. This time in seconds divided by that required for the flow of 200 cc. of water is the specific viscosity of the oil. It is usual, in testing oils, to state the viscosity as the number of seconds required for a given volume of the oil to flow through an orifice, which will pass the same volume of a standard oil, at the same temperature, in a given time

In the absence of a viscosimeter, a moderately accurate test can be made with a large pipette. The pipette should

have a water-jacket, that the oil may be heated to the required temperature and it should be standardized with pure rape-oil or other oil that may easily be obtained in a state of great purity. The time in seconds required for the flow of 50 cc. of the rape-oil is noted by means of a stop-watch. The pipette is then filled with the sample to be tested and its flow is noted under the same conditions as before. According to Redwood the average time required for the flow of 50 cc. of rape-oil, with his viscosimeter, is 535 seconds at 60° F. and the viscosity of the oil under examination in terms of the viscosity of rape-oil is calculated as follows: Multiply the number of seconds required for the flow of 50 cc. of the oil by 100 and divide the product by 535 (seconds required for the flow of 50 cc. of rape-oil at 60° F.); multiply this quotient by the specific gravity of the oil under examination, at the temperature of the experiment, and divide by .915 the specific gravity of rape-oil at 60° F.

It is very difficult to graduate the orifice of a pipette to give the desired flow. For houses of large size using considerable quantities of oil, it is desirable to provide a viscosimeter. The viscosity test is the most important in judging the suitability of the oil for the required purpose.

272. Tests for Acidity and Alkalinity.—Shake a portion of the oil with hot distilled water in a test-tube. After the oil and water separate on standing, test the latter for acidity and alkalinity. It should be neutral to test-paper. Oils are usually treated with sulphuric acid followed by washing with water and caustic soda. The acid especially should be completely removed, otherwise the bearings of the machinery may be injured.

273. Purity Tests.—Boil a portion of the oil with distilled water, and after allowing the two to separate, examine the latter, which should remain clear and transparent.

In testing a mineral oil for admixture with animal or vegetable fats and oils, proceed as follows by the saponification method: Transfer a weighed portion of the oil, e.g., 2 grams, to a pressure-bottle, and heat it in a water- or steam-bath with 25 cc. of alcoholic potash solution. This solution is prepared by dissolving 40 grams of good caustic potash in one litre of 95 per cent alcohol. The solution must be

filtered if not perfectly clear. The flasks used in the Kjel-
dahl nitrogen determination are suitable pressure-bottles.
The stopper of the bottle must be tied down with strong
twine. Continue the heating about one hour, revolving the
flask from time to time to mix its contents. A parallel
experiment should be made in blank, with the reagent only.
Cool the bottles to the room temperature and titrate the
contents with half-normal hydrochloric acid (**300**), using
phenolphthalein as an indicator. In the absence of animal
and vegetable fats and oils, the results of the two titrations
should be the same. Should a saponifiable oil be present
as indicated by the titration, remove the alcohol by distilla-
tion, transfer the residue to a separatory funnel, and extract
it several times with ether to remove the mineral oil; evapo-
rate the ether solution and weigh the residue. The saponi-
fiable matter *i.e.*, animal or vegetable oil, is determined by
the difference.

The saponification test may also be conducted, as de-
scribed above, in a closed flask, but without alcohol. Pour
2 cc. of a solution containing 100 grams of the pure potas-
sium hydroxide in 58 grams of hot distilled water, upon
2 grams of the oil; heat one hour as before; cool, and
transfer the contents of the flask to a separatory funnel and
extract the mineral oil with ether; evaporate the ether, and
weigh the residue, consisting of the mineral oil. Should the
residue weigh less than 2 grams saponifiable bodies are
present.

ANALYSIS OF FLUE-GASES.

274. Remarks on Flue-gases.—The analysis of flue-gases is made for the purpose of ascertaining whether the full efficiency of the fuel is being obtained and also occasionally with a view to utilizing the carbonic acid in the carbonatation process.

For these purposes the ordinary volumetric analysis is usually employed and the constituents are reported in volume per cents. The constituents determined are carbonic acid (CO_2), carbonic oxid (CO), oxygen (O), and nitrogen (N).

275. Preparation of the Apparatus and Reagents.—The most convenient apparatus for this analysis is that of Crsat, Fig. 97. A form of this apparatus having a 4-way stopcock instead of those on the pipettes B, C, D and G is often used, but that illustrated is easier to manipulate and is preferable.

The apparatus consists of a water-jacketed burette A, for the measurement of the gases and three absorption U tubes B, C, D, with suitable connections and stopcocks. The absorption branches of the U tubes are filled with pieces of small-bore glass tubing to increase the surface exposed to the gases.

The absorption-tubes are connected with the burette by barometer tubing of very small bore. The branches of the U tubes at the rear are usually connected with a soft rubber bulb (not shown in the figure), to prevent exposing the solutions to the air and thus weakening them. The water-jacket on the burette is for maintaining a fairly constant temperature during the test.

The following solutions are used in the absorption-tubes:

For tube B : Use a concentrated solution of caustic potassium (KHO) of about 60° Brix.

For tube C: Dissolve 5 parts of pyrogallic acid in 50 parts of hot water and add 100 parts of caustic-potassium solution of approximately 50° Brix.

For tube D: This tube is to be filled with a solution of cuprous chloride prepared as follows: Dissolve 35 grams of cupric chloride in a small quantity of water and add to the solution sufficient stannous chloride to change its color.
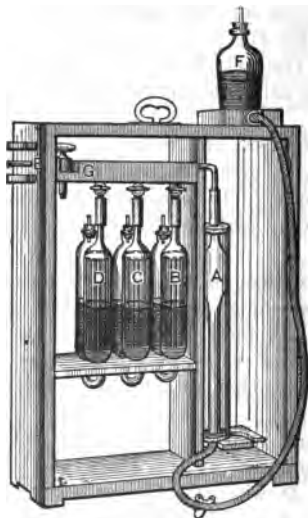
FIG. 97.

Cuprous chloride, insoluble in water, separates as a white crystalline precipitate. Wash the precipitate several times with distilled water, by decantation, and after the last washing pour off the water close to the precipitate. In these manipulations the cuprous chloride should be exposed as little as possible to the air. Wash the precipitate into a bottle with 200 cc. of concentrated hydrochloric acid and dilute the solution with about 120 cc. of water. Place a few pieces of copper wire or copper turnings in the bottle, stopper it, and use the solution from time to time as required in U tube *D*. Each of the glass tubes in *D* should have a piece of copper wire in it.

The following method may also be used in preparing the cuprous chloride: Place 35 grams of cupric chloride in a bottle, add 200 cc. of concentrated hydrochloric acid and a quantity of copper turnings or copper foil. Stopper the bottle and set it aside for two days, shaking it occasionally, then add 120 cc. water.

Ready prepared cuprous chloride may be obtained of the dealers, and used, instead of making it in the laboratory.

The U tubes should be filled half full of the solutions and the rubber bulb then connected with the branches, or in lieu of the bulb, oil may be poured on the surfaces of the liquids. The bulb is preferable, however.

276. Sampling of Flue-gases and their Analysis.— A piece of half-inch iron pipe should be inserted into each flue, leading to the chimney, reaching about half-way to the center of the flue. A double-acting rubber-bulb pump, with suitable valves, is used in drawing the gas from the flue and discharging it into a soft rubber bulb used as a receiver. The bulb should be filled with the gases and emptied several times, to expel all the air it or the pump may contain, and then be filled with the sample and its rubber tube closed with a pinch-cock. It is convenient to have a number of these bulbs so that duplicate samples may be drawn from each flue.

In analyzing the samples proceed as follows: Fill the bottle F, Fig. 97, with distilled water, close the cocks on BC and D and open the 3-way cock G to the air; lift F until the water fills the burette to the upper mark, then close the 3-way cock and pinch-cock on the rubber tube connecting F with the burette, and place F on the table.

A U tube containing a little water and a light plug of cotton in each branch is connected at E.

Open the pinch-cock and then cautiously open the cock on the U tube B and let the caustic-potassium solution rise to the mark on the upper part of the tube, lowering F still more if the pressure is not sufficient. Fill the tubes C and D in the same way, filling the burette with water each time by altering the position of the bottle F. With the absorption branch of each U tube filled with its solution and the burette with water, the apparatus is ready for the

tests. Connect the sample-bulb with the small U tube on
E and permit a little of the gas to escape into the air through
the side branch of the 3-way cock G, to expell the air or
previous sample from the connections.

Open the cock to G to connect with the apparatus, and
the pinch-cock on the water-tube and let the gas displace the
water in the burette. Hold the bottle F, so that the level
of the water in it will be level with the zero of the burette,
disconnect the sample-bulb and manipulate the cock G so
that the levels of the water in the bottle and burette will
be the same. Lift the bottle F and caut:ously open the
cock on B, and let the gas displace the caustic potassium,
filling and emptying the U tube with gas by manipulating
the bottle, but at no time letting the water rise above the
1C0 mark on the burette. The caustic potassium solution
will absorb the carbonic acid. As soon as absorption ceases,
hold the bottle with the surface of the water in it at the level
of that in the burette and note the burette reading, which is
the percentage of carbonic acid (CO_2). Next repeat these
manipulations with the residue of the gas using U tube C.
Note the total reading of the burette and subtract the first
reading from it to obtain the percentage of oxygen (O).
Again proceed with the last residue of gas as before, using
U tube D. The second burette reading subtracted from
the third gives the percentage of carbonic oxide (CO). The
final residue usually consists almost entirely of nitrogen (N)
and the percentage is obtained by subtracting the third
burette reading from 100. The gases may contain very small
quantities of sulphuretted hydrogen and sulphurous acid;
these introduce a slight error in the determinations.

Sulphuretted hydrogen is tested for with filter-paper
moistened with lead acetate or subacetate, which turns
black in the presence of the gas.

Sulphurous acid may be detected by shaking a little of
the gas in a test-tube with iodized starch solution. If this
acid is present the blue color is discharged.

After each analysis the residual gas should be expelled
from the apparatus and the burette left filled with water.
The cocks should be well greased with a mixture of vaseline
and mutton tallow.

THE QUALITY OF THE WATER-SUPPLY, AND TREATMENT OF IMPURE WATER.

THE chemical composition of the water supplied to a diffu-sion-battery is of importance. A water may be so heavily charged with mineral matter and organic impurities as to seriously affect the quality of the diffusion-juices. The essen-tial requirements for water used in the milling process, except for the generation of steam, are that it be cool and clean.

277. Treatment of Waste Waters from the Sugar-house. — It is often necessary to economize the waste waters and return them to the sugar-house. Such waters, if required for the condensers of the vacuum apparatus must be cooled. The most practical plan of accomplishing this cooling is by means of a water-tower. Such a tower, as usually constructed in Cuba and in beet-sugar countries, consists of a framework several stories in height. The floor-timbers of each story, in Europe, are usually covered with wil-lows. The entire structure should extend 30 feet or more above the ground. The waste-water is pumped from the sugar-house to the top of the tower, and then flows or drips down through openings in the framework or through the wil-lows from floor to floor, and is finally collected in a pond. This treatment lowers the temperature of the water very considerably, and also improves its quality by the oxidation of the organic matter.

In case of very impure and acid waters to be used in the diffusion-battery, the addition of lime in slight excess is an advantage. The excess of lime is completely precipitated by the carbonic acid of the air.

278. The Water-supply for the Diffusion-bat-tery.—The amount of solid matter contained in the water should be determined, and if in excess of .3 part per 1000 it should be submitted to a quantitative analysis. If the

analysis shows a large proportion of sulphate of calcium, the water should be rejected even if the solids are not in excess of .3 part per 1000. For methods for the examination of waters, see works on quantitative analysis. So far as possible in the selection of water for a diffusion-battery, that containing sulphate of sodium or calcium, or the chlorides of magnesium, calcium, etc., should be avoided, since these salts are melassigenic, and in the concentration of the juices would accumulate to a sufficient extent to materially affect the crystallization of the sugar. Sulphate of calcium deposits on the tubes of the heaters, and is difficult to remove; it also continues to be deposited in the evaporation, and forms incrustations on the tubes of the multiple effect apparatus. Bicarbonates of lime and magnesia are decomposed in the cells of the battery, and are deposited on the chips and impede the diffusion.

In seeking to improve waters containing sulphate of lime, we substitute sodium for the lime, still leaving a very melassigenic salt in solution; but we obtain a salt which is not deposited on heating its solutions, or to a serious extent in the concentration of the juices.

For the improvement of waters proceed as follows:

To waters containing bicarbonates of lime and magnesia, add milk of lime in slight excess. The normal carbonates are formed and precipitated.

To waters containing sulphate of lime, add sodium carbonate. The lime is precipitated and the sodium sulphate remains in solution.

To waters containing bicarbonates of lime and magnesia and the chlorides and sulphates of these bases, add milk of lime and caustic soda.

Many organic and mechanical impurities are removed by certain systems of filtration, employing alum or chloride of iron as a coagulant.

Sodium may be substituted for lime and magnesia by filtration through zeolite as in the permutite process. The zeolite is regenerated by treating it with a common salt solution, the sodium replacing the lime and magnesia.

FERMENTATION.

279. Fermentation.—*Ferment.*—Any substance capable of producing fermentation.

Vinous or alcoholic fermentation.—Liquid disturbed; rise in temperature and increase in volume; carbonic acid escapes, forming peculiar bubbles on the surface of the liquid. A temperature between 15° and 18° C. is favorable to this fermentation; between 18° and 30° the fermentation proceeds very rapidly; it is checked below 15° C. and ceases entirely below 12° C.

Acetic fermentation.—The favorable temperatures are between 20° and 35° C. The liquid becomes turbid, and is filled with a ropy substance. Finally, the solution clears up and acetic acid is formed. Use lime to check this fermentation.

Putrid fermentation.—This fermentation follows the acetic stage. The solution becomes turbid and viscous; ammonia is set free, and a sediment deposits. The fetid odor is repulsive.

Viscous fermentation.—The solution becomes thick, slimy, ropy; and starchy matters and sugar are transformed into gummy substances. This fermentation takes place spontaneously. A mucilaginous appearance is characteristic. Small quantities of carbonic acid and hydrogen are liberated. Wash the tanks with a dilute sulphuric-acid solution to eliminate this ferment (5-per cent solution of 66° acid).

Lactic fermentation.—This fermentation takes place spontaneously, and may exist in the presence of the viscous ferment. Odor acrid, taste very disagreeable. This ferment is checked by acidity; hence use sulphuric acid in washing the tanks.

Mucous fermentation.—Sugar-cane juices are attacked by this ferment in the presence of nitrogenous bodies and the air. Mannite, gum and carbonic acid are formed. The liquid becomes thick and ropy.

SPECIAL REAGENTS.

280. Litmus Solution.—This solution may be prepared either (*a*) directly from pure azolitmin or (*b*, *c*) by separating this coloring matter from crude litmus. The crude litmus should not be used without purification of the azolitmin in the preparation of either the solution or the test-paper, since the other coloring matters present impair the sensibility.

(*a*) Dissolve 1 gram of pure azolitmin in 100 cc. of dilute alcohol containing about 20 cc. of 85 per cent alcohol, by weight. Filter the solution and preserve it as indicated in (*b*).

(*b*) Boil 100 grams of commercial litmus with 600 cc. of distilled water and set it aside to cool and deposit the residue. Decant the clear solution and evaporate it on the water-bath to about 200 cc. Filter the concentrate and dilute the filtrate to 300 cc. with distilled water and add 100 cc. of diluted sulphuric acid containing 16.2 grams of the pure concentrated acid. Heat the mixture four hours on the water-bath with frequent stirring. Collect the precipitate which forms and wash it with cold water, until the washings assume a peculiar fiery red color and on addition of caustic alkali a deep blue and not a violet color. Reject the washings and dissolve out the purified coloring-matter with 100 cc. luke-warm 90 per cent alcohol to which a few drops of ammonia have been added. Distill off the alcohol, after filtration, and evaporate the residue to dryness on the water-bath. Dissolve the dried residue in 600 cc. of distilled water and neutralize the solution with sodium hydrate. The neutral solution should have a pure violet tint.

Litmus solution decomposes when stored in a stoppered bottle. It should be kept in a salt-mouth bottle, which should be only half filled with the solution, and a loose plug of cotton should be placed in the mouth of the bottle to keep out dust and admit air.

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[1] A. Puschel, Oest. Chem. Zeit., **13**, 185.

(c) Exhaust powdered litmus with successive portions of hot alcohol to remove the coloring-matter that accompanies the azolitmin. Digest the residue in cold water acidulated with sulphuric or hydrochloric and reject the solution. Treat the residue with boiling water to extract the azolitmin and then filter the solution. The filtrate should be neutralized and preserved as in (b).

281. Litmus Papers.—These papers are prepared by soaking filter-paper in acid (red), neutral and alkaline (blue) azolitmin solution. The paper should be of the best quality and be thoroughly washed. Well-washed quantitative filter-paper is suitable. A paper is sometimes used to which the solution is only applied to one side, the other being left white for comparisons.

The neutral paper is prepared by soaking the paper in the azolitmin solution obtained by one of the methods of the previous paragraph. The sheet of paper should be drawn over a glass rod to remove the surplus solution, and then hung to dry in a room free of laboratory fumes. The sheet should be occasionally turned when first hung to prevent the solution from accumulating at the edges by drainage.

The red paper is prepared as above, but from an azolitmin solution that has been faintly acidulated with sulphuric. The acidulation is conveniently and efficiently accomplished as follows: Divide the azolitmin solution into two equal parts and faintly acidulate one and then mix the two. Repeat this proceeding until the mixture is very faintly red. Test the sensitiveness of the solution by soaking a strip of filter-paper in it. The paper should be slightly red when dried. Proceed as above in preparing an alkali solution for the blue paper, except using a dilute sodium hydrate solution.

282. Turmeric or Curcuma Paper.—Digest powdered commercial turmeric or curcumin in water to remove all water-soluble coloring-matter. This repeated digestion is best conducted by decantation. Treat the residue with alcohol to dissolve the curcumin. Neutralize the solution with dilute caustic soda solution and soak filter-paper in it. On account of the usual acidity of paper, the solution may even be slightly alkaline. Dry the paper by suspending the sheet from a line with clips and then again soak it in the curcumin solution,

this having in the meantime been again neutralized. Again dry the paper and repeat these operations until an exceedingly sensitive paper is obtained. This paper turns a reddish brown with alkali and yellow with acid. The neutral paper just verges on a brown tint. This paper is usually sufficiently sensitive for all factory purposes. The curcumin may be extracted to form a purer solution by the following method:

Evaporate the alcoholic solution, obtained as in the preceding method, to dryness and extract the residue with ether. Filter this extract and remove the ether from the solution by distillation and dry the residue. Dissolve the residue in alcohol and precipitate the curcumin from this solution with acetate of lead. After washing this precipitate with alcohol, suspend it in water and decompose it with hydrogen sulphide gas. Collect the precipitate on a filter and wash it with water and then dry it. Dissolve the curcumin from the precipitate with ether and remove this solvent by evaporation. The residue is very pure curcumin.

Turmeric or curcuma paper of sufficient sensitiveness for the control of the ordinary defecation process is made by the first method. This paper was at one time much used in the control of the first carbonation. It is not satisfactory for this use on account of the disturbing influence of carbonic acid and the carbonates of sodium and potassium. Normal sulphites are alkaline to turmeric.

Turmeric paper is very useful in the control of the ordinary defecation process. The paper is turned a reddish brown by lime and this color may easily be seen by artificial light. Cane-juice that has very slight turmeric alkalinity in the cold usually becomes neutral on heating, due to the combination of the lime with the organic acids at the higher temperature.

283. Phenolphthalein Solution.—Dissolve 1 gram of phenolphthalein in 100 cc. of diluted alcohol and neutralize it with acid or alkali as may be necessary. For use in the defecation of cane-juice, especially in raw-sugar work, the solution prepared as above is too sensitive. For this purpose it should be acidulated until it has about the same sensitiveness as a good litmus paper.

284. Phenolphthalein or Dupont Paper.—This paper is made by soaking the very finest quality of filter- or

glazed paper in an alcoholic solution of phenolphthalein. Dupont regulated the sensitiveness of the paper by adding dilute sulphuric acid to the alcoholic solution and made the sensitiveness correspond to different proportions of lime or other alkalinity of juices. This paper is much used in the control of sulphitation processes.

285. Corallin or Rosalic Acid Solution.—Digest equal quantities of carbolic, sulphuric, and oxalic acid together for some time at 150° C.; dilute the mixture with water, saturate the free acid with calcium carbonate and evaporate the mixture to dryness; extract the coloring-matter with alcohol and nearly neutralize the solution (Sutton). A solution of commercial corallin in 90 per cent alcohol, nearly neutralized, may be used.

For determining the alkalinity or acidity of molasses (**137**) the alcohol-soluble corallin used as a stain in microscopy is recommended.

286. Cochineal Solution.—Extract 3 grams of pulverized cochineal with 50 cc. of strong alcohol and 200 cc. of water, with occasional agitation, for a day or two. Filter and neutralize the extract.

287. Phenacetolin Solution.—Dissolve 2 grams of the reagent in 1000 cc. of strong alcohol and neutralize the solution.

288. Iodate Paper.—Dissolve 2 grams of starch in 100 cc. of water with heating and add 0.2 gram of iodate of potassium, dissolved in 5 cc. of water. Soak filter-paper in this solution and dry it.

This paper is used in testing for sulphurous acid, which, even in slight traces, frees the iodine and colors the paper blue through the reaction with the starch.

289. Nessler's Solution.—Dissolve 62.5 grams of potassium iodide in 250 cc. of water. Set aside about 10 cc. of this solution; add to the larger portion a solution of mercuric chloride until the precipitate formed no longer redissolves. Add the 10 cc. of potassium iodide solution; then continue the addition of mercuric chloride very cautiously until only a slight permanent precipitate forms. Dissolve 150 grams of caustic potash in 150 cc. water, cool and add it gradually to the above solution. Dilute the mixture to 1 liter.

290. Subacetate of Lead.—*Concentrated Solution.*—Heat, nearly to boiling, for about half an hour, 860 grams of neutral lead acetate, 260 grams of litharge, and 500 c̀c. of water. Add water to compensate for the loss by evaporation. Cool, settle, and decant the clear solution.

This solution may be preapred without heat, provided the mixture is set aside several hours, with frequent shaking.

Dilute Solution.—Proceed as described above, except use 1000 c̀c. of water. The solution should be diluted with cold, recently boiled, distilled water to 54.3° Brix.

291. Preparation of Bone-black for Decolorizing Solutions.—Powder bone-black and digest it several hours with hot hydrochloric or nitric acid to dissolve the mineral matter. Decant the acid and wash the bone-black with water until the washings no longer turn blue litmus paper red. Dry the powdered bone-black in an air bath, at about 150° C. and preserve it in a tightly stoppered jar.

292. Hydrate of Alumina.—This reagent is also frequently called "alumina cream."

To a saturated solution of common alum in water add ammonia little by little until in slight excess, then enough additional alum to render the solution slightly acid to litmus paper. The sulphates may remain in solution to precipitate the excess of lead.

When precipitation of the lead is not wished, the hydrate of alumina should be washed by decantation with water until it contains only traces of sulphates.

293. Preparation of Pure Sugar.—The following method of purifying sugar, for use in testing polariscopes, was adopted by the Fourth International Congress of Applied Chemistry, Paris, 1900, on the recommendation of the committee appointed with a view to unifying the methods of sugar analysis used in various countries: Prepare a hot saturated solution of the purest commercial sugar obtainable, and precipitate the sugar with absolute ethel alcohol. Spin the precipitated sugar in the laboratory centrifugal and wash it with alcohol. Redissolve and reprecipitate the sugar as before, washing it in the centrifugal with alcohol. The sugar so obtained should be dried between pieces of blotting-paper and preserved in a stoppered jar. The mois-

ture in the sugar should be determined and proper allowance made for it when weighing the sample for analysis

H. W. Wiley recommends the following method for sugar of beet or unknown origin: Dissolve 70 parts of high grade sugar in 30 parts of water, then precipitate the sugar from this solution at 60° C. with an equal volume of 90 per cent alcohol. Decant the supernatant liquid, while still warm, and wash the sugar with strong, warm alcohol. The raffinose, which beet sugar may contain, is removed in the alcohol solution. Finally wash the sugar with absolute alcohol and dry it over sulphuric acid in a desiccator.

The writer prefers Wiley's method of drying to that of the International Congress, as, in the latter, fibers of paper may adhere to the product.

294. Preparation of Invert-sugar Solution.[1]— Dissolve 2.375 grams of pure sucrose in water and dilute it to 100 cc. Add 10 cc. hydrochloric acid, of 1.188 specific gravity and let the mixture stand over night or about fifteen hours at the room temperature to invert the sucrose. After inversion, dilute the solution with water nearly neutralize it with very dilute sodium hydrate solution, and complete the volume to 1000 cc. with water. Twenty cubic centimeters of this solution contain 0.05 gram of invert-sugar.

295. Fehling's Solution.—The formula for Fehling's solution is as follows:

> 34.64 grams of pure crystalline copper sulphate;
> 150.00 grams neutral potassium tartrate.

Dissolve the copper sulphate in 160 cc. distilled water; dissolve the neutral potassic tartrate in 600 to 700 cc. caustic-soda solution, specific gravity 1.12, equivalent to approximately a 14-per cent solution, by volume; add the copper solution to the alkali, stirring thoroughly after each addition, and dilute to 1000 cc.

Fehling solution decomposes readily on exposure to strong light. The author prefers Violette's solution for commercial work by a volumetric method.

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[1] Zeit. Angew. Chem., 1892, 333.

296. Violette's Solution.—This solution should be prepared in small quantities at a time, since it is liable to deposit oxide of copper, even in the cold, on long exposure to light.   To prepare this solution proceed as follows:

34.64 grams chemically pure crystallized sulphate of copper;
187.00 grams chemically pure tartrate of soda and potash
        (Rochelle salt);
 78.00 grams chemically pure caustic soda.

Dissolve the copper sulphate, accurately weighed, in 140 cc. water and add it slowly to the solution of Rochelle salt and caustic soda, taking care to thoroughly stir the solution after each addition.   Dilute the solution to one liter.

The copper sulphate should be carefully examined for impurities.   Considerable quantities of iron have been found in copper sulphate from one of the most reputable manufacturers.   If the salt is impure it must be dissolved and recrystallized repeatedly.   The crystals must be finely powdered and dried between filter-papers before weighing.

If it is desirable to make up a large quantity of Fehling's or Violette's solution, all risk of deposition of the copper oxide in the cold may be avoided by making a separate solution of the copper sulphate.   Dissolve the alkali and dilute it to one liter; dissolve the copper and make it up to exactly one liter.   Use 10 cc. of each of the solutions and omit the addition of water, as usual with Violette's solution.

Check this reagent with invert-sugar (**294**) under the conditions of the analytical method.   The copper in 10 cc. of the Violette's solution should be reduced by 0.05 gram invert-sugar.

297. Soxhlet's Solution. — In Soxhlet's method two solutions are employed, prepared as follows:

(A) 34.639 grams of copper sulphate dissolved in water and diluted to 500 cc.

(B) 173 grams tartrate of soda and potash (Rochelle salt) dissolved in water and mixed with 100 cc. caustic soda solution containing 516 grams caustic soda per liter and the volume is completed to 500 cc.   Chemically pure salts should be used.

298. Soldaini's   Solution.—Dissolve 40 grams of

sulphate of copper and 40 grams of carbonate of sodium separately in water; mix the solutions, collect the precipitate on a filter and wash it with cold water. Transfer the precipitate to a large flask fitted with a reflux condenser; a long glass tube will answer for this purpose. Add approximately 416 grams of bicarbonate of potassium, and in all 1400 cc. distilled water; heat on a water-bath or a hot plate several hours or until the evolution of carbonic acid ceases. When no more carbonic acid is given off, filter the solution and boil the filtrate a few minutes, then cool and dilute it to 2000 cc. The specific gravity of the solution should be approximately 1.185. Solutions to be treated with Soldaini's reagent should be boiled in case they contain ammonia to insure freedom from this substance.

299. Normal Acid and Alkali Solutions.—According to Sutton [1] "Normal solutions, as a rule, are so prepared that one liter shall contain the hydrogen equivalent of the active reagent weighed in grams $(H = I)$." Thus normal sulphuric acid contains 49.043 grams H_2SO_4 per liter; normal hydrochloric acid, 36.458 grams HCl per liter, etc. Half-normal, one-fifth normal, and one-tenth normal (decinormal) solutions are frequently used, and are prepared by diluting the normal solutions. Normal, half-normal one-fifth normal solutions, etc., are usually indicated as follows: $N, \dfrac{N}{2}, \dfrac{N}{5}, \dfrac{N}{10}$, etc. These solutions are prepared and checked as described in the following sections.

300. Standard Hydrochloric Acid.—The reagent acid has usually a specific gravity of 1.20, approximately. Acid of this specific gravity contains 40.78 per cent of hydrochloric acid, hence a little less than 100 grams of it are required to contain the 36.458 grams necessary to form a normal solution. It is advisable to dilute a somewhat larger quantity of the acid, e.g., 80 cc. to 1000 cc., with distilled water, rather than to attempt to closely approximate the correct quantity. Titrate this solution with a normal alkali solution (**304**), measuring the acid from a burette into 10 cc. of the alkali solution, using cochineal or other suitable indicator. The preliminary titration should, most conveniently,

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show the acid solution to be too strong; for example, suppose 9.6 cc. of the acid solution are required to neutralize 10 cc. of the alkali solution, then to 9.6×100 =960 cc. of the acid must be added 1000 −960 cc. =40 cc. of water to make one solution exactly neutralize the other. The solution should be further checked by a determination of its chlorine content. This acid is a convenient one for use in preparing very accurate standard alkali and acid solutions, since its strength may be ascertained with ease and accuracy by a chlorine determination. The half-normal acid is a convenient strength, and should contain 17.725 grams of chlorine per liter.

$$1 \text{ cc. normal hydrochloric acid} = .036458 \text{ gram HCl}$$
$$= .03545 \quad `` \quad \text{Cl}$$
$$= .02804 \quad `` \quad \text{CaO}$$

301. Standard Oxalic Acid.—This is the simplest of the normal solutions to prepare, and when strictly pure oxalic acid can be obtained it may be used in checking the preparation of all the standard alkali and acid solutions.

Repeatedly crystallize the purest obtainable oxalic acid, from water solution. Dry the crystals thoroughly in the air at ordinary temperatures. Reject all crystals that show indications of efflorescence. Dissolve 63.034 grams of this acid in distilled water and dilute to 1000 cc., to prepare the normal solution, or, preferably, dry the powdered acid at 100° C. to constant weight and use 45.018 grams in preparing the normal solution. It is advisable to employ weaker solutions than the normal, usually the one-tenth normal acid. This should be prepared from the normal solution as required, since the latter keeps well, provided it is not exposed to direct sunlight.

$$1 \text{ cc. normal oxalic acid} = .06303 \text{ gram } H_2C_2O_4.2H_2O.$$

302. Standard Sulphuric Acid.—Add approximately 28 cc. of concentrated sulphuric acid to distilled water, cool the solution, and dilute to 1000 cc. Standardize by titration with normal alkali.

1 cc. normal sulphuric acid = .049043 gram H_2SO_4
= .02804 " CaO
= .05181 " SrO
= .07669 " BaO.

303. Standard Sulphuric Acid for the Control of the Carbonatation. — Add approximately 21 cc. of concentrated sulphuric acid to distilled water, cool the solution, and dilute to 1000 cc. Titrate this solution with a normal soda or potash solution, using phenolphthalein as an indicator. Dilute the acid so that 14 cc. of it will be required to neutralize 10 cc. of the normal alkali.

1 cc. this standard acid = .035 gram H_2SO_4
= .02 " CaO.

It is usual to add the phenolphthalein to this solution before dilution to 1000 cc.

304. Standard Alkali Solutions. — Ammonium hydrate (NH_4HO), caustic soda ($NaHO$), and caustic potash (KHO) are used in preparing the alkali solutions. The normal soda or potash solutions are used, but the ammonia should be weaker, preferably decinormal, or, for Sidersky's method for reducing-sugars, half-normal.

Dissolve 42 grams of chemically pure caustic soda in water, in preparing the normal reagent, cool the solution, dilute to 1000 cc. and standardize it by titration against a normal soda. In preparing the potash solution, use 58 grams of chemically pure caustic potash. Standard ammonia is prepared by diluting the reagent to approximately the required strength, and standardizing it by titration with decinormal or half-normal acid, as may be required, using cochineal as an indicator. For Sidersky's method for reducing-sugars, use sulphate of copper as an indicator, as directed on page 251.

1 cc. normal caustic-soda solution = .0401 gram NaOH
= .03105 " Na_2O
1 cc. normal caustic potash solution = .056 " KHO
= .04711 " K_2O
1 cc. half-normal ammonia solution = .00853 " NH_3
= .01754 " $(NH_4)HO$
1 cc. decinormal ammonia solution = .00171 " NH_3
= .00351 " $(NH_4)HO$

Phenolphthalein cannot be used as an indicator with ammonia.

305. Decinormal Permanganate of Potassium.—Dissolve 3.16 grams of chemically pure, dry permanganate of potassium ($KMnO_4$) in distilled water, and dilute to 1000 cc. This solution is conveniently checked by titration with decinormal oxalic acid. To 10 cc. of decinormal oxalic acid add several volumes of water and a few cc. of dilute sulphuric acid. Warm the solution to approximately $C0°$ C., and add the permanganate solution little by little. Discontinue the addition of the permanganate as soon as the solution acquires a faint pink or rose color. The temperature of the solution must be maintained at approximately 60° C., and a little time must be allowed for the reaction.

Permanganate of potassium solution should be preserved in a tightly stoppered bottle, and should be checked from time to time. The formation of a precipitate indicates a change in the solution. It is simpler to determine a factor from time to time, rather than attempt to maintain the solution strictly decinormal.

1 cc. decinormal permanganate of $\left.\begin{array}{l}\\\\\end{array}\right\}$ = .0316 gram $KMnO_4$
    potash $= .00636$ " Cu

306. Permanganate Solution for Reducing-sugar Determinations.—This solution should be of such strength that 1 cc. is equivalent to .01 gram of copper. Dissolve 4.9763 grams of permanganate of potassium in distilled water and dilute to 1000 cc. This solution should be checked by a reducing-sugar determination in material of known composition.

REFERENCE TABLES

FOR USE IN

SUGAR LABORATORIES.

REFERENCE TABLES.

307. TABLE SHOWING THE IMPURITIES PRESENT IN COMMERCIAL REAGENTS; ALSO, THE STRENGTH OF SOLUTIONS, ETC., RECOMMENDED IN ANALYSIS.

NAME.	SYMBOL.	IMPURITIES.	STRENGTH OF SOLUTION, ETC.
Sulphuric Acid (Oil of Vitriol).	H_2SO_4.	Pb, As, Fe, Ca, HNO_3, N_2O_4.	Concentrated and dilute. To dilute pour 1 part acid by measure into 9 parts distilled water. Use porcelain dish.
Nitric Acid.	HNO_3.	H_2SO_4, HCl.	Concentrate and dilute. To dilute add 1 part acid to 9 parts water.
Hydrochloric Acid (Muriatic Acid).	HCl.	Cl, Fe_2Cl_6, H_2SO_4, SO_2, As.	Concentrated and dilute. Dilute = 1 part acid to 9 parts water.
Nitro-hydrochloric Acid. (Aqua regia.)			Prepare when required by adding 4 parts hydrochloric to 1 part nitric acid. Use concentrated acids.
Acetic Acid.	$H_4C_2O_2$.	H_2SO_4, HCl, Cu, Pb, Fe, Ca.	Concentrated and dilute. Dilute = 1 part pure glacial acetic acid to 1 part water.
Sulphurous Acid.	H_2SO_3.		To charcoal, in a flask, add concentrated H_2SO_4. Boil, wash the gas generated by passing it through water, and finally pass it into very cold water. Preserve the solution in tightly-stoppered bottles.
Oxalic Acid.	$H_2C_2O_4$.	Fe, K, Na, Ca.	Dissolve 1 part of crystallized acid in 9 parts distilled water.
Sulphuretted Hydrogen.	H_2S.		Use in gaseous state or in water solution. Wash the gas.
Sodic Hydrate or Potassic Hydrate.	NaHO, KHO.	Al, SiO_2, phosphates, sulphates, and chlorides.	Dissolve the stick soda or potash in 20 parts water. (Soda is less expensive, and will usually answer for most purposes in place of potash.)
Ammonic Hydrate.	NH_4HO.	Sulphate, chloride, carbonate, tarry matters.	Stronger water of ammonia (.96 specific gravity) and ¼ above strength.
Baric Hydrate.	BaO_2H_2.		Dissolve 1 part of the crystals in 20 parts water ; filter, and preserve in stoppered bottle.

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REAGENTS.—*Continued*.

NAME.	SYMBOL.	IMPURITIES.	STRENGTH OF SOLUTION, ETC.
Calcic Hydrate.	CaO$_2$H$_2$.		Slake lime in water, filter off the solution, and preserve out of contact with the air.
Sodic Ammonic Hydric Phosphate. (Microcosmic Salt.)	Na(NH$_4$)HPO$_4$.		Dry and powder the salt. It may be made as follows: Dissolve 7 parts disodic hydric phosphate (Na$_2$HPO$_4$) and 1 part ammonic chloride in 2 parts boiling water, filter, and separate the required salt by crystallization. Purify by recrystallization.
Sodic Biborate.	Na$_2$B$_4$O$_7$.		Heat to expel water of crystallization and powder.
Sodic Carbonate.	Na$_2$CO$_3$.	Chlorides, phosphates, sulphates, silicates.	Use the powdered salt or dissolve in 5 parts water.
Ammonic Sulphate.	(NH$_4$)$_2$SO$_4$.		Dissolve 1 part in 5 parts water.
Ammonic Chloride.	(NH$_4$)Cl.	Fe. Purify the commercial salt by the addition of ammonia; filter. Neutralize filtrate with HCl; concentrate and recrystallize.	Dissolve 1 part in 5 parts water.
Ammonic Nitrate.	(NH$_4$)NO$_3$.		Saturated solution.
Ammonic Oxalate.	(NH$_4$)$_2$C$_2$O$_4$.	Purify by recrystallization.	Dissolve 1 part in 20 parts water.
Ammonic Carbonate.	(NH$_4$)$_2$CO$_3$.	Pb, Fe, sulphates, chlorides.	Dissolve 1 part in 4 parts water, and add 1 part ammonia, specific gravity .880.
Ammonic molybdate.			Dissolve the salt in strong ammonia, decant the clear solution slowly into strong nitric acid, stirring thoroughly till the precipitate redissolves.
Ammonic sulphide.	(NH$_4$)$_2$S.		Saturate 3 parts ammonia with H$_2$S, then add 2 parts ammonia.
Yellow Ammonic Sulphide.	(NH$_4$)$_2$S$_2$		Prepared by dissolving sulphur in ammonic sulphide.
Potassic Sulphate.	K$_2$SO$_4$.		Dissolve 1 part in 10 parts water.
Potassic Iodide.	KI.	Iodate, carbonate.	Dissolve 1 part in 50 parts water.

REAGENTS.—*Continued.*

NAME.	SYMBOL.	IMPURITIES.	STRENGTH OF SOLUTION, ETC.
Potassic Chromate.	K_2CrO_4.	Sulphates.	Dissolve 1 part in 10 parts water.
Potassic Bichromate.	$K_2Cr_2O_7$.		Dissolve 1 part in 10 parts water.
Potassic Ferricyanide.	$K_6Fe_2Cy_{12}$.		Dissolve 1 part in 12 parts water. Better to prepare solution when required.
Potassic Ferrocyanide.	K_4FeCy_6.		Dissolve 1 part in 12 parts water, or, for glucose work, 1 part in 50 parts water.
Baric Chloride.	$BaCl_2$.	Purify the commercial salt by passing H_2S through it and crystallizing.	Dissolve 1 part in 10 parts water.
Baric Nitrate.	$Ba(NO_3)_2$.		Dissolve 1 part in 15 parts water.
Baric Carbonate.	$BaCO_3$.		Add water to the powdered carbonate and preserve in salt-mouthed bottle.
Calcic Chloride	$CaCl_2$.	Fe.	Dissolve 1 part in 5 parts water.
Calcic Sulphate.	$CaSO_4$.		Dissolve as much of the salt as possible in water (in the cold), filter, and preserve the filtrate.
Magnesic Sulphate.	$MgSO_4$.		Dissolve 1 part in 10 parts water.
Ferrous Sulphate.	$FeSO_4$.		Dissolve 1 part in 10 parts cold water.
Ferric Chloride	Fe_2Cl_6.		Dissolve 1 part in 10 parts water.
Cobaltous Nitrate.	$CO(NO_3)_2$.	Fe, Ni, etc.	Dissolve 1 part in 10 parts water.
Cupric Sulphate.	$CuSO_4$.	Fe, Zn.	For sugar work purify by repeated crystallizations. Even the so-called " C. P." salts cannot always be depended upon. For Fehling solution see page 415. For ordinary work dissolve *1* part in 10 parts water.
Mercuric Chloride.	$HgCl_2$.		Dissolve 1 part in 20 parts water.
Mercurous Nitrate.	$Hg_2(NO_3)_2$.		Dissolve 1 part in 20 parts water acidulated with 1.2 part nitric acid. Filter into a bottle containing a little metallic mercury.

REAGENTS.—*Continued.*

NAME.	SYMBOL.	IMPURITIES.	STRENGTH OF SOLUTION, ETC.
Platinic Chloride.	$PtCl_4$.		Dissolve 1 part in 10 parts water.
Argentic Nitrate.	$AgNO_3$.		Dissolve 1 part in 10 parts water.
Stannous Chloride.	$SnCl_2$.		Dissolve pure tin in strong HCl in the presence of platinum. Dilute with 4 volumes dilute HCl. Keep granulated tin in the bottle.

308. INTERNATIONAL ATOMIC WEIGHTS (PARTIAL LIST) FOR 1905.

(From Journal of the American Chemical Society, Vol. XXVII, No.1.)

		O=16	H=1.			O=16.	H=1.
Aluminum. ..	Al	27.1	26.9	Magnesium. ...	Mg	24.36	24.18
Antimony...	Sb	120.2	119.3	Manganese....	Mn	55.0	54.6
Arsenic......	As	75.0	74.4	Mercury......	Hg	200.0	198.5
Barium	Ba	137.4	136.4	Molybdenum. .	Mo	96.0	95.3
Bismuth.....	Bi	208.5	206.9	Nickel........	Ni	58.7	58.3
Boron.......	B	11.0	10.9	Nitrogen.	N	14.04	13.93
Bromine.....	Br	79.96	79.36	Oxygen.......	O	16.00	15.88
Cadmium....	Cd	112.4	111.6	Phosphorus. ..	P	31.0	30.77
Calcium.....	Ca	40.1	39.7	Platinum......	Pt	194.8	193.3
Carbon......	C	12.00	11.91	Potassium. ...	K	39.15	38.85
Chlorine.	Cl	35.45	35.18	Radium......	Ra	225	223.3
Chromium. ..	Cr	52.1	51.7	Selenium......	Se	79.2	78.6
Cobalt......	Co	59.0	58.55	Silicon.......	Si	28.4	28.2
Copper......	Cu	63.6	63.1	Silver.	Ag	107.93	107.11
Fluorine....	F	19	18.9	Sodium.	Na	23.05	22.88
Gold........	Au	197.2	195.7	Strontium.....	Sr	87.6	86.94
Hydrogen...	H	1.008	1.000	Sulphur.......	S	32.06	31.82
Iodine......	I	126.97	126.01	Tin	Sn	119.0	118.1
Iron........	Fe	55.9	55.5	Uranium.	U	238.5	236.7
Lead........	Pb	206.9	205.35	Zinc..........	Zn	65.4	64.9

309. TABLES OF EQUIVALENTS OF THE UNITED STATES CUSTOMARY AND METRIC WEIGHTS AND MEASURES.[1]

MISCELLANEOUS EQUIVALENTS.

1 Avoirdupois pound	=	453.5924277 grams.
1 Meter	=	39.37 inches (U. S. law of 1866).
1 U. S. mile	=	1.60935 kilometers.
1 Kilometer	=	0.62137 U. S. mile.
1 Acre	=	0.4047 hectare.
1 Hectare	=	2.471 acres.
1 U. S. liquid ounce	=	29.574 cubic centimeters.
1 U. S. apothecaries' dram	=	3.6967 cubic centimeters.
1 U. S. dry quart	=	1.1012 liters.
1 U. S. bushel	=	0.35239 hectoliters.
1 Long ton (2240 av. lbs.)	=	1016.05 kilograms.
1 Short ton (2000 av. lbs.)	=	907.18 kilograms.
1 Metric ton	=	2204.62 avoirdupois pounds.

[1] From " Tables of Equivalents," 4th Ed., U. S. Bureau of Standards.

TABLES OF EQUIVALENTS.—Continued.

LENGTHS.

Inches.	Millimeters.
0.03937 =	1
0.07874 =	2
0.11811 =	3
0.15748 =	4
0.19685 =	5
0.23622 =	6
0.27559 =	7
0.31496 =	8
0.35433 =	9
1	= 25.4001
2	= 50.8001
3	= 76.2002
4	=101.6002
5	=127.0003
6	=152.4003
7	=177.8004
8	=203.2004
9	=228.6005

Inches.	Centimeters.
0.3937 =	1
0.7874 =	2
1	= 2.54001
1.1811 =	3
1.5748 =	4
1.9685 =	5
2	= 5.08001
2.3622 =	6
2.7559 =	7
3	= 7.62002
3.1496 =	8
3.5433 =	9
4	=10.16002
5	=12.70003
6	=15.24003
7	=17.78004
8	=20.32004
9	=22.86005

Feet.	Meters.
1	= 0.304801
2	= 0.609601
3	= 0.914402
3.28083	= 1
4	= 1.219202
5	= 1.524003
6	= 1.828804
6.56167	= 2
7	= 2.133604
8	= 2.438405
9	= 2.743205
9.84250	= 3
13.12333	= 4
16.40417	= 5
19.68500	= 6
22.96583	= 7
26.24667	= 8
29.52750	= 9

AREAS.

Square Inches.	Square Millimeters.
0.00155 =	1
0.00310 =	2
0.00465 =	3
0.00620 =	4
0.00775 =	5
0.00930 =	6
0.01085 =	7
0.01240 =	8
0.01395 =	9
1	= 645.16
2	=1,290.33
3	=1,935.49
4	=2,580.65
5	=3,225.81
6	=3,870.98
7	=4,516.14
8	=5,161.30
9	=5,806.40

Square Feet.	Square Meters.
1	=0.09290
2	=0.18581
3	=0.27871
4	=0.37161
5	=0.46452
6	=0.55742
7	=0.65032
8	=0.74323
9	=0.83613
10.764	=1
21.528	=2
32.292	=3
43.055	=4
53.819	=5
64.583	=6
75.347	=7
86.111	=8
96.875	=9

TABLES OF EQUIVALENTS.—*Continued.*

VOLUMES.

Cubic Inches	Cubic Cent.
0.0610 = 1	1 = 16.3872
0.1220 = 2	2 = 32.7743
0.1831 = 3	3 = 49.1615
0.2441 = 4	4 = 65.5486
0.3051 = 5	5 = 81.9358
0.3661 = 6	6 = 98.3230
0.4272 = 7	7 = 114.7101
0.4882 = 8	8 = 131.0973
0.5492 = 9	9 = 147.4845

Cubic Feet	Cubic Meters
1	= 0.02832
2	= 0.05663
3	= 0.08495
4	= 0.11327
5	= 0.14159
6	= 0.16990
7	= 0.19822
8	= 0.22654
9	= 0.25485
35.314 = 1	
70.629 = 2	
105.943 = 3	
141.258 = 4	
176.572 = 5	
211.887 = 6	
247.201 = 7	
282.516 = 8	
317.830 = 9	

CAPACITIES.

U.S. Liquid Gallons	Liters
0.26417 = 1	
0.52834 = 2	
0.79251 = 3	
1	= 3.78543
1.05668 = 4	
1.32085 = 5	
1.58502 = 6	
1.84919 = 7	
2	= 7.57087
2.11336 = 8	
2.37753 = 9	
3	= 11.35630
4	= 15.14174
5	= 18.92717
6	= 22.71261
7	= 26.49804
8	= 30.28348
9	= 34.06891

MASSES.

Grains	Grams
1	= 0.06480
2	= 0.12960
3	= 0.19440
4	= 0.25920
5	= 0.32399
6	= 0.38879
7	= 0.45359
8	= 0.51839
9	= 0.58319
15.4324 = 1	
30.8647 = 2	
46.2971 = 3	
61.7294 = 4	
77.1618 = 5	
92.5941 = 6	
108.0265 = 7	
123.4589 = 8	
138.8912 = 9	

Avoirdupois Pounds	Kilograms
1	= 0.45359
2	= 0.90718
2.20462 = 1	
3	= 1.36078
4	= 1.81437
4.40924 = 2	
5	= 2.26796
6	= 2.72155
6.61387 = 3	
7	= 3.17515
8	= 3.62874
8.81849 = 4	
9	= 4.08233
11.02311 = 5	
13.22773 = 6	
15.43236 = 7	
17.63698 = 8	
19.84160 = 9	

310. MENSURATION.

Parallelogram: Area of any parallelogram = base × altitude; area of rhombus = product of two adjacent sides × sine of angle included between them.

Trapezium: Area = (diagonal × sum of perpendicular let fall on it from opposite angles) ÷ 2 = Area of the two triangles into which it may be divided.

Trapezoid: Area = half the sum of the two parallel sides × the perpendicular distance between them.

Any Quadrilateral: Divide the quadrilateral into two triangles and find the sum of the areas of these, or area = half the product of the two diagonals × the sine of the angle at their intersection.

Triangle: Area = base × half the altitude = half the product of two sides × the sine of the included angle = half the sum of the three sides minus each side severally; multiply this half sum and the three remainders together and extract the square root of the product. Area of an equilateral triangle = one fourth the square of one of its sides × 0.433013.

Hypothenuse and one side of a right-angled triangle being given to find the other side: Required side = $\sqrt{\text{Hypothenuse}^2 - \text{given side}^2}$; if the two sides are equal, side = hypothenuse × 0.7071.

Area given to find base: Base = 2 × area ÷ perpendicular height.

Area given to find height: Height = 2 × area ÷ base.

Two sides and base given to find perpendicular height, both angles at base are acute: Base : sum of the sides :: difference of the sides : difference of the divisions of the base made by drawing the perpendicular. Half this difference added to or subtracted from half the base will give the divisions of it.

Polygon: Area of irregular polygon; draw diagonals dividing the polygon into triangles and find the sum of the areas of these.

Area of regular polygon: Area = (length of a side × perpendicular distance of side to center × number of sides)

÷2 =half the perimeter×perpendicular distance of side to center.

Perpendicular to center=half of one side×cotangent of the angle subtended by half the side.

Irregular Figure (Laboratory method): Draw the figure on paper of uniform thickness and cut it out; compare the weight of this piece with that of a sheet of the paper of known area.

Circle: Ratio of circumference .to diameter = 3.1415929 (usually taken as 3.1416). This number is usually represented by the Greek letter *pi*, π.

Circumference = diameter×π.

Length of an arc: 360 : number of degrees of the arc :: circumference of the circle : length of the arc, or diameter of the circle×number of degrees in the arc×0.0087266 = length of the arc.

Area of a circle=square of the radius×π=square of diameter×0.7854.

Areas of circles are to each other as the squares of their diameters.

Ellipse: Area=product of the semi-axes×3.1416=product of the axes×0.7854.

Prism: Area = (perimeter of base×altitude) +areas of the two ends.

Volume=area of base×altitude.

Pyramid: Convex surface of a regular pyramid = perimeter of base×half the slant height.

Volume = area of base×one third of altitude.

Area of a frustum of a regular pyramid=Half the slant height×sum of the perimeters of the two bases (=convex surface) +area of the two bases.

Volume of a frustum of a regular pyramids=sum of areas of the two bases and a mean proportional between them×one third of the altitude. (Mean proportional between two numbers = square root of their product).

Rectangular Prismoid (a solid bounded by six planes, of which two bases are rectangles, having corresponding sides parallel, and the four upright sides are trapezoids): Volume = (sum of the areas of the bases+four times the

area of a parallel section equidistant from the bases) ✕ one sixth of the altitude.

Cylinder: Area of convex surface = circumference of base ✕ altitude. Convex surface + the two end areas = total area.

   Volume of a cylinder = area of base ✕ altitude.

Cone: Total area = circumference of base ✕ half slant height (= convex surface) + area of the base.

   Volume of a cone = area of base ✕ one third of altitude.

   Frustum of a cone: Area = (half the side ✕ sum of the circumferences of the two bases) + area of the two bases.

   Volume of frustum of a cone = (area of two bases + a mean proportional between them ✕ one third of the altitude. (*See* Volume of a frustum of a pyramid relative to a mean proportional.)

Parabola: Area = base ✕ ⅔ altitude.

Sphere: Surface = diameter ✕ circumference of its great circle = square of diameter ✕ 3.1416 = convex surface of its circumscribing cylinder.

   Surfaces of spheres are to each other as the squares of their diameters.

   Volume of a sphere = surface ✕ one third of the radius = cube of the diameter ✕ 0.5236.

   Volumes of spheres are to each other as the cubes of their diameters.

Cask: Volume of a cask in U. S. gallons = (39 ✕ square of bung diameter + 25 ✕ square of head diameter + 26 ✕ the product of the diameters) ✕ length ÷ 26,470.

Molasses Tanks, Crystallizers: *See* table **356.**

311. TABLE SHOWING THE EVAPORATION OF WATER IN CONCENTRATING JUICE TO SIRUP.

(Percentages by Weight.)

Brix of Juice.	Degree Brix of the Sirup and the Evaporation in Percentage Terms of the Juice.									
	52.0	52.5	53.0	53.5	54.0	54.5	55.0	55.5	56.0	56.5
11.0	78.8	79.0	79.2	79.4	79.6	79.8	80.0	80.2	80.4	80.5
.2	78.4	78.6	78.8	79.0	79.2	79.4	79.6	79.8	80.0	80.2
.4	78.0	78.2	78.5	78.7	78.9	79.0	79.3	79.5	79.7	79.8
.6	77.7	77.9	78.1	78.3	78.5	78.7	78.9	79.1	79.3	79.5
.8	77.3	77.5	77.7	78.0	78.2	78.4	78.6	78.8	78.5	79.1
12.0	76.9	77.1	77.4	77.6	77.8	78.0	78.2	78.4	78.6	78.8
.2	76.5	76.7	77.0	77.2	77.4	77.6	77.8	78.0	78.2	78.4
.4	76.1	76.3	76.6	76.8	77.0	77.2	77.5	77.7	77.9	78.1
.6	75.8	76.0	76.3	76.5	76.7	76.9	77.2	77.4	77.6	77.8
.8	75.4	75.6	75.9	76.1	76.3	76.5	76.8	77.0	77.2	77.4
13.0	75.0	75.2	75.5	75.7	75.9	76.1	76.4	76.6	76.8	77.0
.2	74.6	74.8	75.1	75.3	75.5	75.7	76.0	76.2	76.4	76.6
.4	74.2	74.4	74.7	74.9	75.1	75.3	75.6	75.8	76.0	76.2
.6	73.9	74.1	74.4	74.6	74.8	75.0	75.2	75.4	75.6	75.8
.8	73.5	73.7	74.0	74.2	74.4	74.6	74.8	75.0	75.2	75.4
14.0	73.1	73.3	73.6	73.8	74.1	74.3	74.6	74.8	75.0	75.2
.2	72.7	72.9	73.2	73.4	73.7	73.9	74.2	74.4	74.6	74.8
.4	72.3	72.5	72.9	73.1	73.3	73.6	73.8	74.0	74.2	74.4
.6	72.0	72.1	72.5	72.7	72.9	73.2	73.5	73.7	74.0	74.2
.8	71.6	71.8	72.1	72.3	72.6	72.8	73.2	73.4	73.6	73.8
15.0	71.2	71.4	71.7	71.9	72.2	72.5	72.8	73.0	73.2	73.4
.2	70.8	71.0	71.3	71.5	71.8	72.1	72.4	72.6	72.8	73.0
.4	70.4	70.6	70.9	71.1	71.4	71.8	72.1	72.3	72.5	72.7
.6	70.0	70.3	70.6	70.8	71.0	71.4	71.7	71.9	72.1	72.3
.8	69.6	69.9	70.2	70.4	70.7	71.0	71.3	71.5	71.7	71.9
16.0	69.2	69.5	69.8	70.1	70.4	70.7	70.9	71.2	71.4	71.7
.2	68.8	69.1	69.4	69.7	70.0	70.2	70.5	70.8	71.1	71.3
.4	68.4	68.7	69.1	69.4	69.6	69.9	70.2	70.4	70.7	70.9
.6	68.0	68.3	68.7	69.0	69.3	69.5	69.8	70.1	70.4	70.6
.8	67.7	68.0	68.3	68.6	68.9	69.2	69.4	69.7	70.0	70.3
17.0	67.3	67.6	67.9	68.2	68.5	68.8	69.1	69.4	69.7	69.9
.2	66.9	67.2	67.5	67.8	68.1	68.4	68.8	69.1	69.4	69.6
.4	66.5	66.8	67.1	67.4	67.7	68.0	68.4	68.7	69.1	69.3
.6	66.2	66.5	66.8	67.1	67.4	67.7	68.0	68.3	68.6	68.8
.8	65.8	66.1	66.4	66.7	67.0	67.3	67.7	68.0	68.3	68.5
18.0	65.4	65.7	66.0	66.4	66.7	67.0	67.3	67.6	67.9	68.2
.2	65.0	65.3	65.6	66.0	66.3	66.6	66.9	67.2	67.5	67.8
.4	64.6	64.9	65.2	65.6	65.9	66.2	66.6	66.9	67.2	67.5
.6	64.2	64.5	64.8	65.2	65.5	65.8	66.2	66.5	66.8	67.1
.8	63.8	64.1	64.4	64.8	65.1	65.4	65.8	66.1	66.4	66.7
19.0	63.4	63.8	64.2	64.5	64.8	65.1	65.4	65.8	66.1	66.4
.2	63.0	63.4	63.8	64.1	64.4	64.7	65.0	65.4	65.7	66.0
.4	62.6	63.0	63.4	63.7	64.0	64.3	64.7	65.1	65.4	65.7
.6	62.3	62.7	63.1	63.4	63.7	64.0	64.3	64.7	65.0	65.3
.8	61.9	62.3	62.7	63.0	63.3	63.6	64.0	64.4	64.7	65.0
20.0	61.5	61.9	62.3	62.6	63.0	63.3	63.6	64.0	64.3	64.6
.2	61.1	61.5	61.9	62.2	62.6	62.9	63.2	63.6	63.9	64.2
.4	60.7	61.1	61.5	61.8	62.2	62.5	62.9	63.3	63.6	63.9
.6	60.4	60.8	61.2	61.5	61.9	62.2	62.6	63.0	63.3	63.6
.8	60.0	60.4	60.8	61.1	61.5	61.8	62.2	62.6	62.9	63.2
21.0	59.6	60.0	60.4	60.8	61.1	61.5	61.8	62.2	62.5	62.8

TABLE SHOWING THE EVAPORATION OF WATER IN CONCENTRATING JUICE TO SIRUP.—*Continued.*

Brix of Juice.	Degree Brix of the Sirup and the Evaporation in Percentage Terms of the Juice.									
	57.0	57.5	58.0	58.5	59.0	59.5	60.0	60.5	61.0	61.5
11.0	80.7	80.9	81.0	81.2	81.4	81.5	81.7	81.8	82.0	82.1
.2	80.3	80.5	80.7	80.9	81.1	81.2	81.4	81.5	81.7	81.8
.4	80.0	80.2	80.4	80.5	80.7	80.8	81.0	81.2	81.3	81.5
.6	79.6	79.8	80.1	80.2	80.3	80.5	80.7	80.8	81.0	81.1
.8	79.3	79.5	79.7	79.9	80.0	80.2	80.3	80.5	80.7	80.8
12.0	79.0	79.2	79.3	79.5	79.7	79.9	80.0	80.2	80.4	80.5
.2	78.6	78.8	79.0	79.1	79.3	79.5	79.7	79.9	80.0	80.1
.4	78.3	78.5	78.6	78.8	78.9	79.2	79.3	79.5	79.7	79.8
.6	78.0	78.2	78.3	78.5	78.6	78.8	79.0	79.2	79.4	79.5
.8	77.6	77.8	77.9	78.1	78.3	78.5	78.7	78.8	79.0	79.2
13.0	77.2	77.4	77.6	77.8	78.0	78.2	78.3	78.5	78.7	78.9
.2	76.8	77.0	77.2	77.4	77.6	77.8	78.0	78.2	78.4	78.5
.4	76.4	76.6	76.9	77.1	77.3	77.5	77.7	77.9	78.0	78.2
.6	76.0	76.2	76.5	76.8	77.0	77.2	77.3	77.5	77.5	77.9
.8	75.7	75.8	76.2	76.4	76.6	76.8	77.0	77.2	77.4	77.5
14.0	75.4	75.6	75.9	76.1	76.3	76.5	76.7	76.9	77.0	77.2
.2	75.0	75.2	75.5	75.7	75.9	76.1	76.3	76.5	76.7	76.9
.4	74.6	74.8	75.2	75.4	75.6	75.8	76.0	76.2	76.4	76.6
.6	74.4	74.6	74.8	75.0	75.2	75.5	75.7	75.9	76.1	76.3
.8	74.0	74.2	74.5	74.7	74.9	75.1	75.3	75.5	75.7	75.9
15.0	73.7	73.9	74.2	74.4	74.6	74.8	75.0	75.2	75.4	75.6
.2	73.2	73.4	73.8	74.0	74.2	74.5	74.7	74.9	75.1	75.3
.4	72.9	73.1	73.5	73.7	73.9	74.1	74.3	74.5	74.8	74.9
.6	72.5	72.7	73.1	73.3	73.5	73.8	74.0	74.2	74.4	74.6
.8	72.1	72.3	72.8	73.0	73.2	73.5	73.7	73.9	74.1	74.3
16.0	71.9	72.1	72.4	72.6	72.9	73.1	73.3	73.6	73.8	74.0
.2	71.5	71.7	72.1	72.3	72.5	72.8	73.0	73.2	73.5	73.6
.4	71.1	71.3	71.7	72.0	72.2	72.4	72.7	72.9	73.1	73.3
.6	70.9	71.1	71.4	71.6	71.9	72.1	72.3	72.5	72.8	73.0
.8	70.5	70.8	71.0	71.3	71.5	71.8	72.0	72.2	72.5	72.7
17.0	70.2	70.4	70.7	71.0	71.2	71.5	71.7	71.9	72.1	72.4
.2	69.8	70.0	70.3	70.6	70.8	71.1	71.3	71.6	71.8	72.0
.4	69.5	69.7	70.0	70.3	70.5	70.8	71.0	71.2	71.5	71.7
.6	69.0	69.2	69.7	69.9	70.2	70.4	70.7	70.9	71.1	71.4
.8	68.7	68.9	69.3	69.6	69.8	70.1	70.3	70.6	70.8	71.1
18.0	68.4	68.7	69.0	69.2	69.5	69.8	70.0	70.3	70.5	70.7
.2	68.0	68.3	68.6	68.9	69.1	69.4	69.7	69.9	70.1	70.4
.4	67.7	68.0	68.3	68.5	68.8	69.1	69.3	69.6	69.8	70.1
.6	67.3	67.6	67.9	68.2	68.5	68.7	69.0	69.2	69.5	69.8
.8	67.0	67.3	67.6	67.9	68.1	68.4	68.7	68.9	69.1	69.4
19.0	66.7	67.0	67.2	67.5	67.8	68.1	68.3	68.6	68.8	69.1
.2	66.3	66.6	66.9	67.2	67.5	67.7	68.0	68.2	68.5	68.8
.4	66.0	66.3	66.5	66.8	67.1	67.4	67.7	67.9	68.2	68.5
.6	65.6	65.9	66.2	66.5	66.8	67.0	67.3	67.6	67.8	68.1
.8	65.3	65.6	65.9	66.2	66.4	66.7	67.0	67.3	67.5	67.8
20.0	64.9	65.2	65.5	65.8	66.1	66.4	66.7	67.0	67.2	67.5
.2	64.5	64.8	65.2	65.5	65.7	66.0	66.3	66.6	66.9	67.2
.4	64.2	64.5	64.8	65.1	65.4	65.7	66.0	66.3	66.6	66.8
.6	63.9	64.2	64.5	64.8	65.1	65.4	65.7	65.9	66.2	66.5
.8	63.5	63.8	64.1	64.4	64.7	65.1	65.3	65.6	65.9	66.2
21.0	63.2	63.5	63.8	64.1	64.4	64.7	65.0	65.3	65.6	65.8

312. TABLE SHOWING THE EVAPORATION OF WATER IN CONCENTRATING JUICE TO SIRUP.

(Percentages by Volume.)

Degree Brix of the Sirup and the Evaporation in Percentage Terms of the Juice.

Brix of Juice	53.0	53.5	54.0	54.5	55.0	55.5	56.0	56.5	57.0	57.5	58.0	58.5	59.0	59.5	60.0	60.5	61.0	61.5	62.0	62.5	63.0
10.0	84.3	84.5	84.7	84.9	85.0	85.2	85.3	85.5	85.7	85.8	86.0	86.2	86.3	86.5	86.6	86.7	86.8	86.9	87.1	87.3	87.4
.5	83.5	83.7	83.9	84.1	84.3	84.5	84.6	84.8	85.0	85.2	85.3	85.4	85.6	85.8	85.9	86.0	86.1	86.2	86.4	86.6	86.7
11.0	82.7	82.9	83.1	83.3	83.5	83.7	83.8	84.0	84.2	84.4	84.6	84.7	84.8	85.0	85.1	85.3	85.4	85.6	85.8	86.0	86.1
.5	81.9	82.1	82.3	82.5	82.7	82.9	83.0	83.2	83.5	83.6	83.9	84.0	84.1	84.3	84.4	84.6	84.7	84.9	85.1	85.3	85.4
12.0	81.0	81.3	81.4	81.6	81.9	82.0	82.2	82.5	82.7	82.9	83.1	83.3	83.4	83.6	83.7	83.9	84.1	84.3	84.4	84.6	84.7
.5	80.2	80.4	80.6	80.9	81.1	81.2	81.5	81.8	82.0	82.3	82.4	82.5	82.7	82.9	83.0	83.2	83.4	83.6	83.7	83.9	84.1
13.0	79.3	79.6	79.8	80.0	80.3	80.4	80.7	80.9	81.0	81.4	81.6	81.8	82.0	82.2	82.3	82.5	82.7	82.9	83.1	83.3	83.5
.5	78.5	78.7	78.9	79.3	79.5	79.7	79.9	80.1	80.4	80.6	80.8	81.1	81.3	81.5	81.6	81.8	82.0	82.2	82.4	82.6	82.8
14.0	77.7	77.9	78.1	78.4	78.7	78.9	79.1	79.3	79.6	79.8	80.0	80.3	80.5	80.7	80.9	81.1	81.3	81.5	81.7	82.0	82.2
.5	76.9	77.1	77.3	77.6	77.8	78.1	78.3	78.5	78.8	79.0	79.3	79.5	79.8	80.0	80.2	80.4	80.6	80.8	81.1	81.3	81.4
15.0	76.0	76.3	76.5	76.8	77.1	77.5	77.7	77.9	78.1	78.4	78.5	78.8	79.0	79.2	79.4	79.6	79.9	80.1	80.3	80.5	80.7
.5	75.2	75.4	75.6	75.9	76.3	76.5	76.7	76.9	77.2	77.4	77.6	77.8	78.0	78.2	78.5	78.7	79.0	79.2	79.5	79.8	80.0
16.0	74.3	74.6	75.1	75.3	75.5	75.7	75.9	76.1	76.5	76.7	77.0	77.1	77.5	77.8	78.0	78.2	78.4	78.7	78.9	79.1	79.3
.5	73.4	73.8	74.0	74.3	74.5	74.7	75.1	75.4	75.6	75.9	76.1	76.3	76.5	76.8	77.0	77.2	77.4	77.7	77.9	78.1	78.6
17.0	72.6	72.9	73.3	73.6	73.9	74.1	74.4	74.6	74.9	75.1	75.3	75.5	75.8	76.1	76.3	76.6	76.9	77.1	77.4	77.7	77.9
.5	71.8	72.1	72.4	72.7	73.0	73.2	73.5	73.7	74.0	74.2	74.4	74.7	75.0	75.3	75.5	75.8	76.0	76.3	76.6	77.0	77.2
18.0	70.9	71.3	71.5	71.8	72.1	72.4	72.7	72.9	73.1	73.3	73.9	74.1	74.3	74.6	74.8	75.1	75.4	75.6	76.0	76.3	76.5
.5	70.0	70.3	70.5	70.9	71.2	71.5	71.8	72.0	72.5	72.7	73.1	73.3	73.7	73.9	74.1	74.4	74.7	74.9	75.3	75.6	75.8
19.0	69.1	69.5	69.8	70.1	70.4	70.7	71.0	71.3	71.7	71.9	72.2	72.4	72.7	73.0	73.3	73.6	73.9	74.1	74.4	74.7	75.1
.5	68.2	68.6	68.9	69.3	69.6	69.9	70.3	70.5	70.9	71.1	71.5	71.8	72.2	72.6	72.9	73.1	73.4	73.7	74.0	74.2	74.4
20.0	67.4	67.7	68.1	68.4	68.8	69.1	69.4	69.7	70.1	70.3	70.6	71.0	71.4	71.8	72.1	72.3	72.7	73.0	73.3	73.5	73.7
.5	66.4	66.9	67.2	67.6	68.0	68.3	68.5	68.9	69.3	69.6	69.9	70.1	70.6	70.9	71.3	71.6	71.9	72.2	72.4	72.6	73.0
21.0	65.5	65.9	66.3	66.8	67.5	67.8	68.0	68.3	68.5	68.9	69.2	69.6	69.9	70.2	70.5	70.8	71.1	71.4	71.7	72.0	72.3
.5	64.5	65.0	65.6	65.9	66.5	66.8	67.1	67.4	67.7	68.0	68.4	68.8	69.1	69.4	69.7	70.0	70.3	70.6	70.9	71.2	71.5

313. CONDENSER-WATER.

Weight per unit weight of water evaporated from juice.[1]
R. S. Norris' tables extended.[1]

For Single Effects (Vacuum-Pans).

Temp. °C of Injection-water.	Temperature of water coming out of condenser in ° C.															
	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60
5	24.7	22.8	21.3	19.9	18.7	17.6	16.7	15.8	15.0	14.3	13.7	13.1	12.6	12.1	11.6	11.2
6	25.6	23.7	22.0	20.0	19.2	18.1	17.1	16.2	15.4	14.7	14.0	13.4	12.8	12.3	11.8	11.4
7	26.7	24.6	22.8	21.2	19.8	18.6	17.6	16.6	15.8	15.0	14.3	13.7	13.1	12.5	12.0	11.6
8	27.9	25.6	23.6	21.9	20.4	18.6	18.0	17.0	16.1	15.3	14.6	13.9	13.3	12.8	12.3	11.8
9	29.2	26.8	24.5	22.7	21.1	19.8	18.6	17.5	16.6	15.7	14.9	14.2	13.6	13.0	12.5	12.0
10	30.6	27.8	25.5	23.5	21.8	20.4	19.1	18.0	17.0	16.1	15.3	14.6	13.9	13.3	12.7	12.2
11	32.1	29.1	26.5	24.4	22.6	21.0	19.7	18.5	17.4	16.5	15.7	14.9	14.2	13.6	13.0	12.5
12	33.6	30.5	27.7	25.4	23.3	21.8	20.3	19.0	17.9	17.0	16.0	15.2	14.5	13.8	13.3	12.7
13	35.8	32.0	29.0	26.5	24.3	22.5	21.0	19.6	18.4	17.4	16.4	15.6	14.8	14.2	13.5	12.9
14	38.0	33.7	30.4	27.6	25.3	23.4	21.7	20.2	19.0	17.9	16.9	16.0	15.2	14.5	13.8	13.2
15	40.4	35.7	31.9	28.8	26.4	24.2	22.5	20.9	19.6	18.4	17.3	16.4	15.6	14.8	14.1	13.5
16	43.2	37.8	33.6	30.3	27.5	25.2	23.3	21.6	20.2	18.9	17.8	16.8	15.9	15.1	14.4	13.8
17	46.5	40.3	35.6	31.8	28.8	26.3	24.2	22.4	20.8	19.5	18.3	17.3	16.3	15.5	14.7	14.4
18	50.3	43.1	37.8	33.5	30.2	27.4	25.1	23.2	21.6	20.1	18.9	17.7	16.8	15.9	15.1	14.4
19	54.8	46.3	40.2	35.4	31.7	28.7	26.2	24.1	22.3	20.8	19.4	18.3	17.2	15.3	15.4	14.7
20	60.1	50.1	43.0	37.6	33.4	30.1	27.3	25.1	23.1	21.5	20.0	18.8	17.7	16.7	15.8	15.0
21	66.7	54.1	46.2	40.0	35.5	31.6	28.6	26.1	24.0	22.2	20.7	19.3	18.2	17.2	16.2	15.4
22	74.9	59.9	49.9	42.8	37.5	33.3	30.0	27.2	25.0	23.1	21.4	20.0	18.7	17.6	16.7	15.8
23	85.6	66.5	54.4	46.0	39.9	35.2	31.5	28.5	26.0	23.9	22.2	20.6	19.3	18.1	17.1	16.2
24	99.6	74.7	59.7	48.9	42.7	37.8	33.2	29.9	27.2	24.9	23.0	21.3	19.9	18.7	17.6	16.6
25	119.3	85.2	66.4	53.2	45.9	39.8	35.1	31.4	28.4	25.9	23.9	22.1	20.5	19.1	18.1	17.0
26	148.8	98.2	74.4	59.5	49.0	42.5	37.2	33.1	29.8	27.1	24.8	22.9	21.3	19.8	18.6	17.5
27	198.1	118.9	84.9	65.5	54.0	45.7	39.6	35.0	31.3	28.3	25.8	23.8	22.0	20.5	19.2	18.0
28	.....	148.3	98.9	74.2	59.3	49.4	42.4	37.1	33.0	29.7	27.0	24.7	22.8	21.2	19.8	18.5
29	.....	197.4	118.5	84.6	65.6	53.9	45.6	39.5	34.8	31.2	28.2	25.8	23.7	21.9	20.4	19.1

30	19.7	21.1	22.7	24.6	26.9	29.6	32.9	37.0	42.2	49.3	59.1	73.9	98.6	147.8
31	20.3	21.9	23.6	25.7	28.2	31.1	34.7	39.3	45.4	53.7	65.6	84.4	118.1	195.8
32	21.0	22.7	24.5	26.8	29.5	32.7	36.8	42.1	49.2	58.9	73.7	98.2	147.3	196.1
33	21.8	23.5	25.6	28.0	31.0	34.6	39.2	45.3	53.4	65.2	84.1	117.6	196.1	
34	22.8	24.4	26.7	29.4	32.6	36.7	41.9	48.9	58.7	73.4	97.9	146.8		
35	23.4	25.5	27.9	30.9	34.5	39.1	45.1	53.3	65.1	83.8	117.2	195.6		
36	24.4	26.6	29.3	32.5	36.6	41.8	48.7	58.5	73.2	97.6	146.2			
37	25.4	27.8	30.7	34.4	38.9	44.9	53.1	64.9	83.5	116.8	194.8			
38	26.5	29.2	32.4	36.5	41.8	48.6	58.3	72.9	97.2	145.8				
39	27.7	30.6	34.2	38.8	44.8	52.9	64.7	83.2	116.5	194.1				
40	29.1	32.3	36.6	41.5	48.5	58.1	72.7	96.9	145.3					
41	30.5	34.1	38.7	44.6	52.8	64.5	82.9	116.0	193.5					
42	32.2	36.5	41.4	48.3	57.9	72.4	96.5	144.7						
43	34.0	38.5	44.5	52.6	64.3	82.7	115.5	192.7						
44	36.4	41.2	48.1	57.7	72.2	96.3	144.3							
45	38.1	44.3	52.4	64.1	82.4	115.3	192.1							
46	41.1	47.7	57.5	71.9	96.0	143.8								
47	44.2	52.3	63.8	82.1	114.9	191.4								
48	47.8	57.3	71.7	95.5	143.4									
49	52.1	63.6	81.4	114.5	190.8									
50	57.1	71.5	95.2	142.9										
51	63.4	81.5	114.0	190.1										
52	71.2	94.9	142.2											
53	81.2	113.5	189.4											
54	94.6	141.8												

CALCULATION OF THE CONDENSER-WATER.

To calculate the condenser-water (W) for other pressures than 25 inches (basis of the tables) and for other evaporator combinations than single-, triple and quadruple-effect, use the following formula, factors and constants:

$$W = \frac{\text{Constant} - \text{T.}^\circ\text{ C. of condenser-water}}{\text{T.}^\circ\text{ C. of condenser-water} - \text{T.}^\circ\text{ C. of injection-water}} + 1.$$

The value of W must be multiplied by the factor appropriate to the evaporator combination.

[1] J. Ind. and Eng. Chem.

CONDENSER WATER.—*Continued.*

For Triple Effects.

Temp. °C. of Injection-water.	Temperature of water coming out of condensers in ° C.															
	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60
5	9.1	8.4	7.9	7.4	6.5	6.5	6.2	5.8	5.6	5.3	4.9	4.9	4.7	4.5	4.3	4.2
6	9.5	8.7	8.1	7.6	7.1	6.7	6.3	6.0	5.7	5.4	5.1	5.0	4.7	4.6	4.4	4.2
7	9.9	9.1	8.4	7.8	7.3	6.9	6.5	6.1	5.8	5.5	5.3	5.1	4.8	4.6	4.5	4.3
8	10.3	9.5	8.7	8.1	7.6	7.1	6.7	6.3	6.0	5.7	5.4	5.2	4.9	4.7	4.5	4.4
9	10.8	9.9	9.1	8.4	7.8	7.8	6.9	6.5	6.1	5.8	5.5	5.3	5.0	4.8	4.6	4.4
10	11.3	10.3	9.4	8.7	8.1	7.5	7.1	6.7	6.3	6.1	5.7	5.4	5.1	4.9	4.7	4.5
11	11.9	10.8	9.8	9.0	8.4	7.8	7.5	6.9	6.6	6.1	5.8	5.5	5.3	5.1	4.8	4.6
12	12.5	11.3	10.2	9.4	8.7	8.1	7.8	7.0	6.8	6.3	6.1	5.6	5.4	5.2	4.9	4.7
13	13.2	11.8	10.7	9.8	9.0	8.3	8.0	7.3	7.0	6.4	6.1	5.8	5.5	5.4	5.0	4.8
14	14.0	12.5	11.2	10.2	9.4	8.6	8.3	7.5	7.2	6.6	6.4	5.9	5.6	5.5	5.1	4.9
15	15.0	13.2	11.8	10.7	9.8	9.0	8.6	7.7	7.5	6.8	6.6	6.1	5.8	5.6	5.2	5.0
16	16.0	14.0	12.4	11.2	10.2	9.3	8.9	8.0	7.7	7.0	6.8	6.2	5.9	5.7	5.3	5.1
17	17.2	14.9	13.2	11.8	10.6	9.7	9.3	8.3	8.0	7.2	7.0	6.4	6.0	5.9	5.5	5.2
18	18.6	15.9	14.0	12.4	11.1	10.1	9.7	8.6	8.3	7.4	7.2	6.6	6.2	6.0	5.6	5.3
19	20.3	17.1	14.9	13.1	11.7	10.6	10.1	8.9	8.6	7.7	7.4	6.8	6.4	6.2	5.7	5.4
20	22.2	18.5	15.9	13.9	12.4	11.1	10.6	9.3	8.9	8.0	7.7	7.0	6.5	6.4	5.9	5.6
21	24.7	20.2	17.1	14.8	13.1	11.7	11.1	9.7	9.2	8.2	7.9	7.2	6.7	6.5	6.0	5.7
22	27.7	22.2	18.5	15.8	13.9	12.3	11.7	10.1	9.6	8.5	8.2	7.4	6.9	6.7	6.2	5.8
23	31.6	24.6	20.1	17.0	14.8	13.0	12.3	10.5	10.1	8.9	8.5	7.6	7.2	6.9	6.3	6.0
24	36.8	27.6	22.1	18.4	15.8	13.8	13.0	11.1	10.5	9.2	8.9	7.9	7.4	7.1	6.5	6.1
25	44.1	31.5	24.5	20.1	17.0	14.7	13.8	11.6	11.0	9.6	9.2	8.2	7.6	7.4	6.7	6.3
26	55.1	36.7	27.5	22.0	18.4	15.7	14.7	12.2	11.6	10.0	9.6	8.5	7.9	7.6	6.9	6.5
27	73.3	44.0	31.4	24.4	20.0	16.9	15.7	12.9	12.2	10.5	10.0	8.8	8.2	7.9	7.1	6.6
28	......	54.9	36.8	27.4	22.0	18.3	16.9	13.7	12.9	11.0	10.4	9.2	8.6	8.1	7.3	6.9
29	......	......	43.8	31.3	24.3	19.9	18.3	14.6	12.9	11.5	10.8	9.5	8.8	8.1	7.6	7.1

30	7.3	7.8	8.7	9.1	10.0	11.0	12.2	13.7	15.6	18.2	21.9	27.4	36.5	54.7
31	7.5	8.1	8.7	9.5	10.4	11.5	12.8	14.5	16.8	19.9	24.3	31.2	43.7	72.9
32	7.8	8.4	9.1	9.9	10.9	12.1	13.6	15.6	18.2	21.8	27.3	36.3	54.9	
33	8.1	8.7	9.4	10.3	11.5	12.8	14.3	16.8	19.8	24.1	31.1	43.5	72.6	
34	8.4	9.0	9.9	10.9	12.1	13.5	15.3	18.1	21.7	27.1	36.2	54.3		
35	8.7	9.4	10.3	11.4	12.7	14.5	16.0	19.7	24.1	30.9	43.4	72.3		
36	9.0	9.8	10.8	12.0	13.4	15.4	18.0	21.6	27.1	36.1	54.1			
37	9.4	10.3	11.3	12.7	14.4	16.6	19.6	24.0	30.9	43.3	72.1			
38	9.8	10.8	11.9	13.5	15.4	18.0	21.5	27.0	35.9	53.9				
39	10.3	11.3	12.6	14.3	16.5	19.5	23.9	30.8	43.1	71.8				
40	10.8	11.9	13.5	15.3	17.9	21.5	26.9	35.8	53.8					
41	11.2	12.6	14.3	16.5	19.5	23.8	30.7	42.9	71.6					
42	11.8	13.4	15.3	17.8	21.4	26.8	35.7	53.6						
43	12.5	14.2	16.5	19.5	23.8	30.6	42.8	71.4						
44	13.3	15.2	17.8	21.3	26.7	35.6	53.6							
45	14.2	16.4	19.4	23.7	30.5	42.7	71.1							
46	15.3	17.7	21.0	26.6	35.5	53.3								
47	16.6	19.3	23.0	30.4	42.5	70.9								
47	17.6	21.2	26.5	35.3	53.1									
49	19.2	23.5	30.3	42.4	70.7									
50	21.1	26.4	35.2	52.9										
51	23.4	30.2	42.6	70.4										
52	26.3	35.1	52.6											
53	30.0	42.1	70.1											
54	35.0	52.4												

Constants.

Inches.	Calories.
22	625.9
23	624.4
24	623.1
25	621.3
26	619.5
27	616.8
28	613.4

Factors.

Single-effect....1.000
Double-effect....0.534
Triple-effect....0.370
Quadruple-effect....0.284
Quintuple-effect....0.235

METHOD OF USING NORRIS' TABLES.

Calculate the evaporation from clarified juice to sirup (E) by the following formula, in which B is the Brix of the juice and b that of the sirup:

$$E = (B - b) \div B \times 100,$$ in terms of the juice.

The next stages of the calculations are best illustrated by an example in quadruple-effect evaporation (continued on page 439):

CONDENSER-WATER.—*Continued.*

FOR QUADRUPLE EFFECTS.

Temp. °C. of Injection-water.	Temperature of water coming out of condenser in °C.															
	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60
5	7.0	6.5	6.0	5.6	5.3	5.0	4.7	4.5	4.3	4.1	3.9	3.7	3.6	3.4	3.3	3.2
6	7.3	6.7	6.2	5.8	5.5	5.1	4.9	4.6	4.4	4.2	4.0	3.8	3.6	3.5	3.4	3.2
7	7.6	7.0	6.5	6.0	5.6	5.3	5.0	4.7	4.5	4.3	4.1	3.9	3.7	3.6	3.5	3.3
8	7.9	7.3	6.7	6.2	5.8	5.4	5.1	4.8	4.6	4.4	4.1	4.0	3.8	3.6	3.5	3.3
9	8.3	7.6	7.0	6.4	6.0	5.6	5.3	4.9	4.7	4.5	4.2	4.0	3.9	3.7	3.6	3.4
10	8.7	7.9	7.2	6.7	6.2	5.8	5.4	5.1	4.8	4.6	4.3	4.1	3.9	3.8	3.7	3.5
11	9.1	8.3	7.5	6.9	6.4	6.0	5.6	5.3	5.0	4.7	4.4	4.3	4.0	3.9	3.7	3.5
12	9.6	8.7	7.9	7.2	6.7	6.2	5.8	5.4	5.1	4.8	4.7	4.4	4.1	3.9	3.8	3.6
13	10.2	9.1	8.2	7.5	6.9	6.4	6.0	5.6	5.2	4.9	4.8	4.5	4.2	4.0	3.9	3.7
14	10.8	9.6	8.6	7.8	7.2	6.6	6.2	5.7	5.4	5.1	4.9	4.7	4.3	4.1	3.9	3.8
15	11.5	10.1	9.1	8.0	7.5	6.9	6.4	5.9	5.5	5.2	5.0	4.8	4.4	4.2	4.0	3.8
16	12.3	10.7	9.6	8.6	7.8	7.2	6.6	6.1	5.7	5.4	5.1	4.9	4.5	4.3	4.1	3.9
17	13.2	11.4	10.1	9.0	8.2	7.5	6.9	6.4	5.9	5.5	5.2	5.0	4.6	4.4	4.2	4.0
18	14.3	12.2	10.7	9.5	8.6	7.8	7.1	6.6	6.1	5.7	5.4	5.2	4.8	4.5	4.3	4.1
19	15.6	13.2	11.4	10.1	9.0	8.1	7.4	6.8	6.3	5.9	5.5	5.2	4.9	4.6	4.4	4.2
20	17.1	14.2	12.2	10.7	9.5	8.5	7.8	7.1	6.6	6.1	5.7	5.3	5.0	4.9	4.5	4.3
21	18.9	15.5	13.1	11.4	10.0	9.0	8.1	7.4	6.8	6.3	5.9	5.5	5.2	4.9	4.6	4.4
22	21.3	17.0	14.2	12.2	10.6	9.5	8.5	7.7	7.1	6.5	6.1	5.7	5.3	5.0	4.7	4.5
23	24.3	18.9	15.4	13.1	11.3	10.0	8.9	8.1	7.4	6.8	6.3	5.9	5.5	5.1	4.7	4.6
24	28.3	21.2	17.0	14.1	12.1	10.6	9.4	8.5	7.7	7.1	6.5	6.1	5.7	5.3	5.0	4.7
25	33.9	24.2	18.8	15.4	13.1	11.3	10.0	8.9	8.1	7.4	6.8	6.3	5.8	5.5	5.1	4.8
26	42.3	28.2	21.1	16.7	14.1	12.1	10.6	9.4	8.5	7.7	7.0	6.5	6.0	5.6	5.4	5.0
27	56.3	33.8	24.1	18.7	15.3	13.0	11.3	9.9	8.9	8.0	7.3	6.8	6.3	5.8	5.5	5.1
28	....	42.2	28.1	21.1	16.9	14.0	12.0	10.5	9.4	8.4	7.7	7.0	6.5	6.0	5.6	5.3
29	....	....	33.6	24.0	18.6	15.3	12.9	11.2	9.9	8.9	8.0	7.3	6.7	6.2	5.8	5.4

30	5.6	6.0	6.5	7.0	7.6	8.4	9.3	10.5	12.0	14.0	16.8	21.0	28.0	42.0
31	5.8	6.2	6.7	7.3	8.0	8.8	9.9	11.1	12.9	15.3	18.6	24.0	33.6	56.0
32	6.0	6.5	7.0	7.6	8.4	9.3	10.4	11.9	13.9	16.7	20.9	27.9	41.8	
33	6.2	6.7	7.3	8.0	8.8	9.8	11.1	12.8	15.2	18.5	23.9	33.4	55.3	
34	6.5	7.0	7.6	8.4	9.3	10.4	11.8	13.9	16.7	20.8	27.9	41.7		
35	6.7	7.3	7.9	8.8	9.8	11.1	12.8	15.1	18.5	23.7	33.3	55.3		
36	7.0	7.6	8.7	9.8	10.4	11.9	13.8	16.6	20.8	27.7	41.5			
37	7.3	7.9	9.7	10.4	11.0	12.7	15.1	18.4	23.7	33.2	55.2			
38	7.6	8.3	10.4	11.0	11.7	13.8	16.5	20.7	27.6	41.4				
39	7.9	8.7	11.0	11.8	12.7	15.0	18.4	23.5	33.1	55.1				
40	8.3	9.2	11.9	12.6	13.8	16.5	20.5	27.5	41.4					
41	8.7	9.7	12.6	13.7	15.0	18.3	23.5	32.9	55.0					
42	9.2	10.3	13.6	14.9	16.4	20.5	27.4	41.1						
43	9.6	10.9	14.9	16.4	18.2	23.5	32.0	54.8						
44	10.8	11.7	16.3	18.2	20.5	27.3	41.0							
45	11.7	12.6	18.1	20.4	23.4	32.7	54.6							
46	12.5	13.6	20.3	23.3	27.2	40.9								
47	13.5	14.8	23.1	27.1	32.6	54.4								
48	14.7	16.3	27.0	32.5	40.7									
49	16.2	18.0	32.4	40.6	54.2									
50	18.0	20.2	40.4	54.0										
51	20.2	23.1	53.8											
52	23.8	26.9												
53	26.8	32.2												
54		40.3												

Weight of mixed juice.........1500 tons
Temperature of injection-water... 35° C.
Temperature of condenser-water . 50° C.
Brix of the juice......... 15
Brix of the sirup......... 60

$E = (60-15) \div 60 \times 100 = 75$ per cent of weight of juice; $1500 \times .75 = 1125$ tons of water evaporated; referring to the third section of the table, opposite 35° and under 50° we have 11.1, the condenser water per unit of water evaporated: $1125 \times 11.1 = 12,488$ tons of condenser-water.

314. TABLE FOR THE REDUCTION OF THE WEIGHT OR VOLUME OF A SIRUP OF A GIVEN DEGREE BRIX OR BAUMÉ TO A SIRUP OF 54.3° BRIX OR 30° BAUMÉ.

Initial Density.		Equivalent Sirup of 54.3° Brix or 30° Baumé.		Initial Density.		Equivalent Sirup of 54.3° Brix or 30° Baumé.	
Degrees Brix.	Degrees Baumé.	Per Cents by Weight.	Per Cents by Volume.	Degrees Brix.	Degrees Baumé.	Per Cents by Weight.	Per Cents by Volume.
35.0	19.6	64.46	59.19	**39.0**	21.8	71.82	67.10
.1	19.65	64.61	59.38	.1	21.8	72.00	67.30
.2	19.7	64.83	59.58	.2	21.9	72.19	67.51
.3	19.8	65.01	59.77	.3	21.9	72.37	67.71
.4	19.8	65.19	59.96	.4	22.0	72.55	67.91
.5	19 9	65.38	60.16	.5	22.05	72.74	68.12
.6	19.9	65.56	60.36	.6	22.1	72.92	68.32
.7	20.0	65.74	60.56	.7	22.2	73.10	68.52
.8	20.0	65.93	60.75	.8	22.2	73.29	68.73
.9	20.1	66.11	60.94	.9	22.3	73.47	68.92
36.0	20.1	66.30	61.14	**40.0**	22.3	73.66	69.12
.1	20.2	66.48	61.33	.1	22.4	73.84	69.32
.2	20 25	66.67	61.53	.2	22.4	74.02	69.52
.3	20.3	66.85	61.72	.3	22 5	74.21	69.73
.4	20 4	67.03	61.92	.4	22.5	74.40	69.93
.5	20 4	67.22	62 12	.5	22.6	74.58	70.14
.6	20.5	67.40	62.31	.6	22.6	74.76	70.34
.7	20.5	67.59	62.50	.7	22.7	74.94	70.54
.8	20.6	67.77	62.70	.8	22.8	75.13	70.74
.9	20.6	67.95	62.91	.9	22.8	75.31	70.94
37.0	20.7	68.14	63.11	**41.0**	22.9	75.50	71.15
.1	20.7	68.32	63 31	.1	22.9	75.68	71.35
.2	20.8	68.50	63 51	.2	23 0	75.87	71.55
.3	20.9	68.69	63.70	.3	23 0	76.06	71.75
.4	20.9	68.87	63.90	.4	23.1	76.24	71.95
.5	21.0	69.06	64.10	.5	23.1	76.42	72.16
.6	21.0	69.24	64.30	.6	23.2	76.60	72.37
.7	21.1	69.42	64.49	.7	23.25	76.78	72.58
.8	21.1	69.61	64.69	.8	23.3	76.97	72.79
.9	21.2	69.79	64.89	.9	23.4	77.16	73.00
38.0	21.2	69.98	65.09	**42.0**	23.4	77.34	73.21
.1	21.3	70.16	65.29	.1	23.5	77.52	73.41
.2	21.35	70.34	65.49	.2	23.5	77.70	73.61
.3	21.4	70.53	65 69	.3	23.6	77.89	73.81
.4	21.5	70.72	65.90	.4	23.6	78.08	74.01
.5	21.5	70.90	66.10	.5	23.7	78.26	74.22
.6	21.6	71.08	66.30	.6	23.7	78.44	74.43
.7	21.6	71.26	66.50	.7	23.8	78.62	74.64
.8	21.7	71.45	66.70	.8	23.8	78.81	74.86
.9	21.7	71.63	66.90	.9	23.9	79.00	75.08

TABLE FOR THE REDUCTION OF THE WEIGHT OR VOLUME OF A SIRUP, ETC.—Continued.

Initial Density.		Equivalent Sirup of 54.3° Brix or 30° Baumé.		Initial Density.		Equivalent Sirup of 54.3° Brix or 30° Baumé.	
Degrees Brix.	Degrees Baumé.	Per Cents by Weight.	Per Cents by Volume.	Degrees Brix.	Degrees Baumé.	Per Cents by Weight.	Per Cents by Volume.
43.0	23.95	79.19	75.29	47.0	26.1	86.55	83.76
.1	24.0	79.37	75.49	.1	26.2	86.73	83.97
.2	24.1	79.55	75.69	.2	26.2	86.91	84.18
.3	24.1	79.74	75.89	.3	26.3	87.10	84.39
.4	24.2	79.92	76.10	.4	26.3	87.29	84.60
.5	24.2	80.11	76.31	.5	26.4	87.47	84.82
.6	24.3	80.29	76.52	.6	26.4	87.65	85.04
.7	24.3	80.47	76.73	.7	26.5	87.83	85.26
.8	24.4	80.66	76.95	.8	26.5	88.02	85.48
.9	24.4	80.85	77.17	.9	26.6	88.21	85.70
44.0	24.5	81.03	77.38	48.0	26.6	88.39	85.92
.1	24.55	81.21	77.59	.1	26.7	88.57	86.13
.2	24.6	81.39	77.80	.2	26.75	88.75	86.35
.3	24.65	81.58	78.01	.3	26.8	88.94	86.57
.4	24.7	81.77	78.22	.4	26.9	89.13	86.79
.5	24.8	81.95	78.43	.5	26.9	89.13	87.01
.6	24.8	82.13	78.64	.6	27.0	89.49	87.23
.7	24.9	82.31	78.85	.7	27.0	89.67	87.45
.8	24.9	82.50	79.06	.8	27.1	89.86	87.67
.9	25.0	82.69	79.27	.9	27.1	90.15	87.89
45.0	25.0	82.87	79.49	49.0	27.2	90.24	88.11
.1	25.1	83.05	79.70	.1	27.2	90.42	88.33
.2	25.1	83.23	79.91	.2	27.3	90.60	88.55
.3	25.2	83.42	80.12	.3	27.3	90.78	88.77
.4	25.2	83.61	80.33	.4	27.4	90.96	88.99
.5	25.3	83.79	80.54	.5	27.4	91.16	89.21
.6	25.4	83.97	80.75	.6	27.5	91.35	89.43
.7	25.4	84.15	80.96	.7	27.6	91.54	89.65
.8	25.5	84.34	81.18	.8	27.6	91.72	89.87
.9	25.5	84.53	81.40	.9	27.7	92.90	90.09
46.0	25.6	84.71	81.61	50.0	27.7	92.08	90.31
.1	25.6	84.89	81.82	.1	27.8	92.26	90.53
.2	25.7	85.07	82.03	.2	27.8	92.45	90.75
.3	25.7	85.26	82.24	.3	27.9	92.63	90.97
.4	25.8	85.45	82.45	.4	27.9	92.82	91.19
.5	25.8	85.63	82.66	.5	28.0	93.00	91.41
.6	25.9	85.81	82.87	.6	28.0	93.19	91.63
.7	25.95	85.99	83.09	.7	28.1	93.37	91.85
.8	26.0	86.18	83.31	.8	28.1	93.55	92.07
.9	26.1	86.37	83.53	.9	28.2	93.73	92.30

TABLE FOR THE REDUCTION OF THE WEIGHT OR VOLUME OF A SIRUP, ETC.—*Continued.*

Initial Density.		Equivalent Sirup of 54.3° Brix or 30° Baumé.		Initial Density.		Equivalent Sirup of 54.3° Brix or 30° Baumé.	
Degrees Brix.	Degrees Baumé.	Per Cents by Weight.	Per Cents by Volume.	Degrees Brix.	Degrees Baumé.	Per Cents by Weight.	Per Cents by Volume.
51.0	28.2	93.92	92.58	55.0	30.4	101.28	101.61
.1	28.3	94.10	92.75	.1	30.4	101.46	101.84
.2	28.35	94.29	92.97	.2	30.5	101.64	102.07
.3	28.4	94.47	93.19	.3	30.5	101.83	102.30
.4	28.5	94.65	93.41	.4	30.6	102.01	102.53
.5	28.5	94.84	93.63	.5	30.6	102.20	102.76
.6	28.6	95.02	93.85	.6	30.7	102.38	102.99
.7	28.6	95.20	94.07	.7	30.7	102.56	103.22
.8	28.7	95.39	94.30	.8	30.8	102.75	103.45
.9	28.7	95.58	94.53	.9	30.8	102.94	103.68
52.0	28.8	95.76	94.77	56.0	30.9	103.13	103.92
.1	28.8	95.94	94.99	.1	30.9	103.31	104.15
.2	28.9	96.13	95.21	.2	31.0	103.49	104.38
.3	28.9	96.31	95.43	.3	31.05	103.68	104.61
.4	29.0	96.50	95.65	.4	31.1	103.86	104.84
.5	29.0	96.68	95.87	.5	31.2	104.05	105.07
.6	29.1	96.87	96.09	.6	31.2	104.23	105.30
.7	29.15	97.05	96.32	.7	31.3	104.41	105.54
.8	29.2	97.23	96.55	.8	31.3	104.60	105.78
.9	29.2	97.42	96.79	.9	31.4	104.78	106.02
53.0	29.3	97.60	97.00	57.0	31.4	104.97	106.26
.1	29.4	97.79	97.25	.1	31.5	105.15	106.49
.2	29.4	97.98	97.48	.2	31.5	105.34	106.72
.3	29.5	98.16	97.71	.3	31.6	105.52	106.95
.4	29.5	98.34	97.94	.4	31.6	105.70	107.18
.5	29.6	98.52	98.17	.5	31.7	105.89	107.41
.6	29.6	98.70	98.40	.6	31.7	106.07	107.65
.7	29.7	98.89	98.63	.7	31.8	106.25	107.89
.8	29.7	99.07	98.86	.8	31.8	106.44	108.13
.9	29.8	99.26	99.08	.9	31.9	106.62	108.37
54.0	29.8	99.44	99.30	58.0	31.9	106.81	108.61
.1	29.9	99.62	99.53	.1	32.0	106.99	108.84
.2	29.9	99.81	99.76	.2	32.0	107.17	109.08
54.3	30.0	100.00	100.00	.3	32.1	107.35	109.32
.4	30.05	100.18	100.22	.4	32.15	107.54	109.56
.5	30.1	100.36	100.45	.5	32.2	107.73	109.80
.6	30.2	100.55	100.68	.6	32.3	107.91	110.04
.7	30.2	100.73	100.91	.7	32.3	108.09	110.28
.8	30.3	100.91	101.14	.8	32.4	108.28	110.52
.9	30.3	101.09	101.37	.9	32.4	108.47	110.76

TABLE FOR THE REDUCTION OF THE WEIGHT OR VOLUME OF A SIRUP, ETC.—*Continued.*

Initial Density.		Equivalent Sirup of 54 3° Brix or 30° Baumé.		Initial Density.		Equivalent Sirup of 54.3° Brix or 30° Baumé.	
Degrees Brix.	Degrees Baumé.	Per Cents by Weight.	Per Cents by Volume.	Degrees Brix.	Degrees Baumé.	Per Cents by Weight.	Per Cents by Volume.
59.0	32.5	108.65	111.00	60.0	33.0	110 49	113.39
.1	32.5	108.83	111.23	.1	33.0	110.68	113.63
.2	32.6	109 02	111.47	.2	33.1	110.86	113.87
.3	32.6	109.20	111.71	.3	33.1	111.04	114.11
.4	32.7	109.38	111.95	.4	33.2	111.23	114.35
.5	32.7	109.56	112.19	.5	33.2	111.41	114.59
.6	32.8	109.75	112.43	.6	33.3	111.60	114.83
.7	32.8	109.93	112.67	.7	33.35	111.78	114.97
.8	32.9	110.12	112.91	.8	33.4	111.96	115.21
.9	32.9	110.30	113.15	.9	33.45	112.14	115.45

The above table is for calculating sirups, within the usual range of densities, to 54.3° Brix, 30° Baumé, for comparison. It is also convenient for use where sirup is purchased at a certain price per gallon of a standard density of 54.3° Brix.

315. Formulæ for Concentration and Dilution.— (1) Having two solutions of known degrees Brix, B and B', to determine the degree Brix of a mixture composed of the volumes, V and V', of these solutions.

$$x = \text{degree Brix required} = \frac{VB + V'B'}{V + V'}.$$

(2) Formula for the calculation of the water required, per cent by weight, to reduce a sugar solution of a given density to any required density.

$x =$ per cent of water required; $B =$ initial degree Brix; $b =$ degree Brix after dilution; $\dfrac{B-b}{B} = E$, and $\dfrac{100E}{1-E} = x$, the per cent required.

(3) Formulæ for the concentration of sugar solutions from stated densities to certain required densities.

444 FORMULÆ FOR CONCENTRATION AND DILUTION

(a) In percentages by weight of original solution:

B = degree Brix after concentration;

b = initial degree Brix;

x = per cent water evaporated in terms of the weight of the original solution.

$$x = \frac{B-b}{B} \times 100.$$

(b) In percentage by volume of the original solution:

G = specific gravity of the solution after concentration;

g = initial specific gravity;

B and b, as in formula (a):

x = per cent water evaporated in terms of the volume of the original solution.

$$x = 100 - 100\frac{gb}{GB}.$$

(4) To determine the volume V of a sugar solution before concentration.

b = degree Brix, and s = the specific gravity of the solution before concentration; B = degree Brix, and S = specific gravity after concentration to a volume of 100.

$$V = \frac{100SB}{sb}.$$

316. TABLE SHOWING A COMPARISON OF THERMOMETRIC SCALES.

(Schubarth's Handbuch der techn. Chem. III. Aufl. I. 61.)

Fahrenheit.	Centigrade.	Réaumur.	Fahrenheit.	Centigrade.	Réaumur.	Fahrenheit.	Centigrade.	Réaumur.
°	°	°	°	°	°	°	°	°
212	100	80	190	87.78	70.22	168	75.55	60.44
211	99.44	79.56	189	87.22	69.78	167	75	60
210	98.89	79.11	188	86.67	69.33	166	74.44	59.56
209	98.33	78.67	187	86.11	68.89	165	73.89	59.11
208	97.78	78.22	186	85.55	68.44	164	73.83	58.67
207	97.22	77.78	185	85	68	163	72.78	58.22
206	96.67	77.33	184	84.44	67.56	162	72.22	57.78
205	96.11	76.89	183	83.89	67.11	161	71.67	57.33
204	95.55	76.44	182	83.33	66.67	160	71.11	56.89
203	95	76	181	82.78	66.22	159	70.55	56.44
202	94.44	75.56	180	82.22	65.78	158	70	56
201	93.89	75.11	179	81.67	65.33	157	69.44	55.56
200	93.33	74.67	178	81.11	64.89	156	68.89	55.11
199	92.78	74.22	177	80.55	64.44	155	68.33	54.67
198	92.22	73.78	176	80	64	154	67.78	54.22
197	91.67	73.33	175	79.44	63.56	153	67.22	53.78
196	91.11	72.89	174	78.89	63.11	152	66.67	53.33
195	90.55	72.44	173	78.33	62.67	151	66.11	52.89
194	90	72	172	77.78	62.22	150	65.55	52.44
193	89.44	71.56	171	77.22	61.78	149	65	52
192	88.89	71.11	170	76.67	61.33	148	64.44	51.56
191	88.33	70.67	169	76.11	60.89	147	63.89	51.11

COMPARISON OF THERMOMETRIC SCALES.—*Continued*.

Fahrenheit.	Centigrade.	Réaumur.	Fahrenheit.	Centigrade.	Réaumur.	Fahrenheit.	Centigrade.	Réaumur.
°	°	°	°	°	°	°	°	°
146	63.33	50.67	83	28.33	22.67	21	−6.11	−4.89
145	62.78	50.22	82	27.78	22.22	20	−6.67	−5.33
144	62.22	49.78	81	27.22	21.78	19	−7.22	−5.78
143	61.67	49.33	80	26.67	21.33	18	−7.78	−6.22
142	61.11	48.89	79	26.11	20.89	17	−8.33	−6.67
141	60.55	48.44	78	25.55	20.44	16	−8.89	−7.11
140	60	48	77	25	20	15	−9.44	−7.56
139	59.44	47.56	76	24.44	19.56	14	−10	−8
138	58.89	47.11	75	23.89	19.11	13	−10.55	−8.44
137	58.33	46.67	74	23.33	18.67	12	−11.11	−8.89
136	57.78	46.22	73	22.78	18.22	11	−11.67	−9.33
135	57.22	45.78	72	22.22	17.78	10	−12.22	−9.78
134	56.67	45.33	71	21.67	17.33	9	−12.78	−10.22
133	56.11	44.89	70	21.11	16.89	8	−13.33	−10.67
132	55.55	44.44	69	20.55	16.44	7	−13.89	−11.11
131	55	44	68	20	16	6	−14.44	−11.56
130	54.44	43.56	67	19.44	15.56	5	−15	−12
129	53.89	43.11	66	18.89	15.11	4	−15.55	−12.44
128	53.33	42.67	65	18.33	14.67	3	−16.11	−12.89
127	52.78	42.22	64	17.78	14.22	2	−16.67	−13.33
126	52.22	41.78	63	17.22	13.78	1	−17.22	−13.78
125	51.67	41.33	62	16.67	13.33	0	−17.78	−14.22
124	51.11	40.89	61	16.11	12.89	−1	−18.33	−14.67
123	50.55	40.44	60	15.55	12.44	−2	−18.89	−15.11
122	50	40	59	15	12	−3	−19.44	−15.56
121	49.44	39.56	58	14.44	11.56	−4	−20	−16
120	48.89	39.11	57	13.89	11.11	−5	−20.55	−16.44
119	48.33	38.67	56	13.33	10.67	−6	−21.11	−16.89
118	47.78	38.22	55	12.78	10.22	−7	−21.67	−17.33
117	47.22	37.78	54	12.22	9 78	−8	−22.22	−17.78
116	46.67	37.33	53	11.67	9.33	−9	−22.78	−18.22
115	46.11	36.89	52	11.11	8.89	−10	−23.33	−18.67
114	45.55	36.44	51	10.55	8.44	−11	−23.89	−19.11
113	45	36	50	10	8	−12	−24.44	−19.56
112	44.44	35.56	49	9.44	7.56	−13	−25	−20
111	43 89	35.11	48	8.89	7.11	−14	−25.55	−20.44
110	43.33	34.67	47	8.33	6.67	−15	−26.11	−20.89
109	42.78	34.22	46	7.78	6.22	−16	−26.67	−21.33
108	42.22	33.78	45	7.22	5.78	−17	−27.22	−21.78
107	41.67	33.33	44	6.67	5.33	−18	−27.78	−22.22
106	41.11	32.89	43	6.11	4.89	−19	−28.33	−22.67
105	40.55	32.44	42	5.55	4.44	−20	−28.89	−23.11
104	40	32	41	5	4	−21	−29.44	−23.56
103	39.44	31.56	40	4.44	3.56	−22	−30	−24
102	38.89	31.11	39	3.89	3.11	−23	−30.55	−24.44
101	38.33	30.67	38	3.33	2.67	−24	−31.11	−24.89
100	37.78	30.22	37	2.78	2.22	−25	−31.67	−25.33
99	37.22	29.78	36	2.22	1.78	−26	−32.22	−25.78
98	36.67	29.33	35	1.67	1.33	−27	−32.78	−26.22
97	36.11	28.89	34	1.11	0.89	−28	−33.33	−26.67
96	35.55	28.44	33	0.55	0.44	−29	−33.89	−27.11
95	35	28	32	0.	0.	−30	−34.44	−27.56
94	34.44	27.56	31	−0.55	−0.44	−31	−35	−28
93	33.89	27.11	30	−1.11	−0.89	−32	−35.55	−28.44
92	33.33	26.67	29	−1.67	−1.33	−33	−36.11	−28.89
91	32.78	26 22	28	−2.22	−1.78	−34	−36.67	−29.33
90	32.22	25.78	27	−2.78	−2.22	−35	−37.22	−29.78
89	31.67	25.33	26	−3.33	−2.67	−36	−37.78	−30.22
88	31.11	24.89	25	−3.89	−3.11	−37	−38.33	−30.67
87	30.55	24.44	24	−4.44	−3.56	−38	−38.89	−31.11
86	30	24	23	−5	−4	−39	−39.44	−31.56
85	29.44	23 56	22	−5.55	−4.44	−40	−40	−32
84	28.89	23.11						

317. TABLE SHOWING A COMPARISON OF THERMOMETRIC SCALES.

Centigrade.	Fahrenheit.	Réaumur.	Centigrade.	Fahrenheit.	Réaumur.	Centigrade.	Fahrenheit.	Réaumur.
°	°	°	°	°	°	°	°	°
100	212	80	62	143.6	49.6	24	75.2	19.2
99	210.2	79.2	61	141.8	48.8	23	73.4	18.4
98	208.4	78.4	60	140	48	22	71.6	17.6
97	206.6	77.6	59	138.2	47.2	21	69.8	16.8
96	204.8	76.8	58	136.4	46.4	20	68	16
95	203	76	57	134.6	45.6	19	66.2	15.2
94	201.2	75.2	56	132.8	44.8	18	64.4	14.4
93	199.4	74.4	55	131	44	17	62.6	13.6
92	197.6	73.6	54	129.2	43.2	16	60.8	12.8
91	195.8	72.8	53	127.4	42.4	15	59	12
90	194	72	52	125.6	41.6	14	57.2	11.2
89	192.2	71.2	51	123.8	40.8	13	55.4	10.4
88	190.4	70.4	50	122	40	12	53.6	9.6
87	188.6	69.6	49	120.2	39.2	11	51.8	8.8
86	186.8	68.8	48	118.4	38.4	10	50	8
85	185	68	47	116.6	37.6	9	48.2	7.2
84	183.2	67.2	46	114.8	36.8	8	46.4	6.4
83	181.4	66.4	45	113	36	7	44.6	5.6
82	179.6	65.6	44	111.2	35.2	6	42.8	4.8
81	177.8	64.8	43	109.4	34.4	5	41	4
80	176	64	42	107.6	33.6	4	39.2	3.2
79	174.2	63.2	41	105.8	32.8	3	37.4	2.4
78	172.4	62.4	40	104	32	2	35.6	1.6
77	170.6	61.6	39	102.2	31.2	1	33.8	.8
76	168.8	60.8	38	100.4	30.4	0	32	0
75	167	60	37	98.6	29.6	−1	30.2	− .8
74	165.2	59.2	36	96.8	28.8	−2	28.4	−1.6
73	163.4	58.4	35	95	28	−3	26.6	−2.4
72	161.6	57.6	34	93.2	27.2	−4	24.8	−3.2
71	159.8	56.8	33	91.4	26.4	−5	23	−4
70	158	56	32	89.6	25.6	−6	21.2	−4.8
69	156.2	55.2	31	87.8	24.8	−7	19.4	−5.6
68	154.4	54.4	30	86	24	−8	17.6	−6.4
67	152.6	53.6	29	84.2	23.2	−9	15.8	−7.2
66	150.8	52.8	28	82.4	22.4	−10	14	−8
65	149	52	27	80.6	21.6	−11	12.2	−8.8
64	147.2	51.2	26	78.8	20.8	−12	10.4	−9.6
63	145.4	50.4	25	77	20			

318. FORMULÆ FOR THE CONVERSION OF THE DEGREES OF ONE THERMOMETRIC SCALE INTO THOSE OF ANOTHER.

$F = \frac{9}{5}C + 32 = \frac{9}{4}R + 32.$ $C = \frac{5}{9}(F - 32) = \frac{5}{4}R.$ $R = \frac{4}{9}(F - 32) = \frac{4}{5}C.$

Additions and subtractions are algebraic.

319. APPROXIMATE TEMPERATURES OF IRON WHEN HEATED UNTIL IT HAS THE FOLLOWING COLORS:

	° F.	° C.		° F.	° C.
Faint red.........	977	525	Orange...........	2021	1170
Dark red.........	1292	700	White............	2370	1300
Cherry-red.......	1652	900	Dazzling white....	2730	1500
Bright cherry-red..	1832	1000		to	to
				2912	1600

320. TABLE SHOWING THE MELTING-POINTS OF THE METALS.

METAL.	Melting-points ° C.	METAL.	Melting-points ° C.
Aluminium..........	657	Lead................	327
Antimony...........	630	Magnesium..........	633
Arsenic.............	449.5	Mercury............	−38.85
Bismuth.............	269	Nickel..............	1435
Cobalt.............	1464	Potassium...........	62.5
Copper.............	1084	Platinum...........	1753
Gold................	1060	Silver..............	962
Iron, cast..........	1075–1275	Sodium.............	97.6
Iron, wrought........	1600	Tin.................	232
Steel................	1373	Zinc................	419

321. TABLE SHOWING THE ALTERATION OF THE VOLUME OF GLASS VESSELS BY HEAT, THE VOLUME AT 15° C. BEING TAKEN AS UNITY.

(From Bailey's "Chemist's Pocket-Book.")

Temp. ° C.	Volume.	Temp. ° C.	Volume.	Temp. ° C.	Volume.
0	.99961210	15	1.00000000	30	1.00028790
1	.99963796	16	1.00002586	35	1.00051720
2	.99966382	17	1.00005172	40	1.00064650
3	.99968968	18	1.00007758	45	1.00077580
4	.99971554	19	1.00010344	50	1.00090510
5	.99974140	20	1.00012930	55	1.00103440
6	.99976726	21	1.00015516	60	1.00116370
7	.99979313	22	1.00018102	65	1.00129600
8	.99981898	23	1.00020688	70	1.00142230
9	.99984484	24	1.00023274	75	1.00155160
10	.99987070	25	1.00025860	80	1.00168090
11	.99989656	26	1.00028446	85	1.00181020
12	.99992242	27	1.00031032	90	1.00193950
13	.99994828	28	1.00033618	95	1.00206880
14	.99997414	29	1.00036204	100	1.00219810

322. COEFFICIENTS OF EXPANSION (CUBICAL) OF ORDINARY GLASS.

EXPANSION PER DEGREE FROM—

0° C. to 100° C.	0° C. to 150° C.	0° C. to 200° C.	0° C. to 250° C.	0° C. to 300° C.
.0000276	.0000284	.0000291	.0000298	.0000306

323. DENSITY (IN GRAMS PER MILLILITER) OF WATER AT TEMPERATURES FROM 0° TO 102° C.[1]

Temp., Deg. C.	Density.	Temp., Deg. C.	Density.	Temp., Deg. C.	Density.
.0	0.99987	35	0.99406	70	0.97781
1	.99993	36	.99371	71	.97723
2	.99997	37	.99336	72	.97666
3	.99999	38	.99299	73	.97607
4	1.00000	39	.99262	74	.97548
5	.99999	40	.99224	75	.97489
6	.99997	41	.99186	76	.97428
7	.99993	42	.99147	77	.97368
8	.99988	43	.99107	78	.97307
9	.99981	44	.99066	79	.97245
10	.99973	45	.99024	80	.97183
11	.99963	46	.98982	81	.97120
12	.99952	47	.98940	82	.97057
13	.99940	48	.98896	83	.96994
14	.99927	49	.98852	84	.96930
15	.99913	50	.98807	85	.96865
16	.99897	51	.98762	86	.96800
17	.99880	52	.98715	87	.96734
18	.99862	53	.98669	88	.96668
19	.99843	54	.98621	89	.96601
20	.99823	55	.98573	90	.96534
21	.99802	56	.98524	91	.96467
22	.99780	57	.98478	92	.96399
23	.99756	58	.98425	93	.96330
24	.99732	59	.98375	94	.96261
25	.99707	60	.98324	95	.96192
26	.99681	61	.98272	96	.96122
27	.99654	62	.98220	97	.96051
28	.99626	63	.98167	98	.95981
29	.99597	64	.98113	99	.95909
30	.99567	65	.98059	100	.95838
31	.99537	66	.98005	101	.95765
32	.99505	67	.97950	102	.95693
33	.99473	68	.97894		
34	.99440	69	.97838		
35	.99406	70	.97781		

[1] According to M. Thiesen, Wiss. Abh. der Physikalisch-Technischen Reichsanstalt, 4, No. 1, 1904.

From Circular No. 19, U. S. Bureau of Standards.

324. WEIGHT OF 1 CUBIC FOOT AND 1 GALLON (U. S. A. 231 cu.in.) OF WATER[1] based on the water densities of P. Chappuis (Bureau International des Poids et Mesures, Travaux et Mémoires, XIII; 1907) for 0° to 40° C. and of M. Thiesen (Wis. Abb. der Physikalisch-Technischen Reichsanstalt, 4, No. 1; 1904) for 41° to 100° C. The weights in air are for dry air at the same temperature as the water up to 40° C. and at a (corrected) barometric pressure of 760 mm. and against brass weights of 8.4 density at 0° C. Above 40° C. the temperature of the air is assumed to be 20° C. The volumetric computations are based on the relation that 1 liter = 1.000027 cubic decimeters, and 1 cubic decimeter = 61.023378 cubic inches.

Temp. ° C.	Weight in Air.			
	1 Cubic Foot.		1 Gallon.	
	Grams.	Pounds.	Grams.	Pounds.
0	28280.254	62.3472	3780.520	8.33461
1	82.033	.3511	0.758	.33613
2	83.321	.3540	0.930	.33551
3	84.121	.3557	1.037	.33575
4	84.458	.3565	1.082	.33585
5	84.345	.3562	1.067	.33582
6	83.784	.3550	0.992	.33565
7	82.804	.3528	0.861	.33536
8	81.413	.3498	0.675	.33495
9	79.618	.3458	0.435	.33442
10	77.441	.3410	0.144	.33378
11	74.853	.3353	3779.798	.33302
12	71.898	.3288	9.403	.33215
13	68.584	.3215	8.960	.33117
14	64.933	.3134	8.472	.33009
15*	60.946	.3046	7.939	.32892
16†	56.630	.2951	7.362	.32765
17	51.985	.2849	6.741	.32628
18	47.040	.2740	6.080	.32482
19	41.766	.2624	5.375	.32327
20	36.193	.2501	4.630	.32162
21	30.321	.2371	3.845	.31989
22	24.157	.2235	3.021	.31808
23	17.694	.2093	2.157	.31617
24	10.954	.1944	1.256	.31419
25	03.930	62.1789	3770.317	.31212
26	28196.629	.1629	3769.341	.30996
27	89.059	.1462	8.329	.30773
28	81.234	.1289	7.283	.30543
29	73.140	.1111	6.201	.30304
30	64.799	.0927	5.086	.30058
31	56.212	.0737	3.938	.29805
32	47.377	.0543	2.757	29545
33	38.311	.0343	1.545	.29278
34	29.005	.0138	0.301	.29003
*15§(60° F.)	28258.580	62.2994	3777.623	8.32820
†16§(62° F.)	28253.57	62.2884	3776.953	8.32670

[1] Calculated by the U. S. Bureau of Standards, Washington, January, 1915.

WEIGHT OF 1 CUBIC FOOT AND 1 GALLON.—*Continued.*

| Temp. ° C. | Weight in Air. | | | |
| | 1 Cubic Foot. | | 1 Gallon. | |
	Grams.	Pounds.	Grams.	Pounds.
35	28119.475	61.9926	3759.027	8.28723
36	09.735	.9713	7.725	.28436
37	28099.771	.9493	6.393	.28142
38	89.596	.9269	5.033	.27842
39	79.215	.9040	3.645	.27536
40	68.645	.8807	2.232	.27225
41	55.68	.8520	0.50	.2684
42	44.62	.828	3749.02	.2652
43	33.30	.803	7.51	.2618
44	21.69	.777	5.96	.2584
45	09.80	.751	4.36	.2549
46	27997.90	.725	2.78	.2514
47	86.01	.698	1.18	.2479
48	73.54	.671	3739.52	.2442
49	61.09	.644	7.85	.2405
50	48.34	.615	6.15	.2368
51	35.60	.587	4.45	.2330
52	22.29	.558	2.67	.2291
53	09.26	.529	0.93	.2253
54	27895.66	.499	3729.11	.2213
55	82.07	.469	7.29	.2173
56	68.20	.439	5.44	.2132
57	55.17	.410	3.70	.2093
58	40.15	.377	1.69	.2049
59	26.00	.346	3719.80	.2007
60	11.55	.314	7.86	.1965
61	27796.83	.281	5.90	.1921
62	82.10	.249	3.93	.1878
63	67.09	.216	1.92	.1834
64	51.80	.182	3709.88	.1789
65	36.50	.148	3707.83	.1744
66	21.21	.115	5.79	.1699
67	05.64	.080	3.70	.1653
68	27689.79	.046	1.58	.1606
69	73.91	.010	3699.46	.1559
70	57.78	60.975	7.31	.1512
71	41.35	.939	5.11	.1463
72	25.21	.903	2.95	.1416
73	08.50	.866	0.72	.1366
74	27591.79	.829	3688.49	.1317
75	75.08	.793	3686.25	.1268
76	57.81	.754	3.94	.1217
77	40.81	.717	1.67	.1167
78	23.53	.679	3679.36	.1116
79	05.97	.640	7.01	.1064
80	27488.42	.602	4.67	.1012
81	70.58	.562	2.28	.0960
82	52.74	.523	3669.90	.0907
83	34.90	.484	7.51	.0855
84	16.77	.444	5.09	.0801

WEIGHT OF 1 CUBIC FOOT AND 1 GALLON.—*Continued.*

Temp. ° C.	Weight in Air.			
	1 Cubic Foot.		1 Gallon.	
	Grams.	Pounds.	Grams.	Pounds.
85	27398.36	60.403	3662.63	8.0747
86	79.96	.362	0.17	.0693
87	61.26	.321	3657.67	.0638
88	42.57	.280	5.17	.0583
89	23.59	.238	2.63	.0527
90	04.62	.196	0.10	.0471
91	27285.65	.154	3647.56	.0415
92	66.38	.112	4.99	.0358
93	46.85	.069	2.37	.0301
94	27.31	.026	3639.76	.0243
95	07.76	59.983	7.15	.0185
96	27187.94	.939	4.50	.0127
97	67.84	.895	1.81	.0068
98	48.01	.851	3629.16	.0009
99	27.62	.806	6.44	7.9949
100	07.51	.762	3.75	.9889

325. TABLE FOR THE CALIBRATION OF FLASKS TO TRUE
CUBIC CENTIMETERS AT 20° C.[1]

Apparent Weight (in Grams) of Water in Air

[This table gives the apparent weight for temperatures between 15°
and 30° C., humidity 50 per cent, unreduced barometer reading
76 cm., of certain volumes of water weighed with brass weights.
The table may be conveniently employed to determine definite
volumes of water for calibrating instruments. The air is assumed
to be at the same temperature as the water.]

Temp.° C.	2000 cc.	1000 cc.	500 cc.	400 cc.	300 cc.	250 cc.	150 cc.
15	1996.11	998.05	499.03	399.22	299.42	249.51	149.71
16	1995.80	997.90	498.95	399.16	299.37	249.48	149.68
17	1995.48	997.74	498.87	399.10	299.32	249.43	149.66
18	1995.13	997.56	498.78	399.03	299.27	249.39	149.63
19	1994.76	997.38	498.69	398.95	299.21	249.34	149.61
20	1994.36	997.18	498.59	398.87	299.15	249.30	149.58
21	1993.95	996.97	498.49	398.79	299.09	249.24	149.55
22	1993.51	996.76	498.38	398.70	299.03	249.19	149.51
23	1993.06	996.53	498.26	398.61	298.96	249.13	149.48
24	1992.58	996.29	498.15	398.52	298.89	249.07	149.44
25	1992.09	996.04	498.02	398.42	298.81	249.01	149.41
26	1991.57	995.79	497.89	398.31	298.74	248.95	149.37
27	1991.04	995.52	497.76	398.21	298.66	248.88	149.33
28	1990.49	995.24	497.62	398.10	298.57	248.81	149.29
29	1989.92	994.96	497.48	397.98	298.49	248.74	149.24
30	1989.33	994.66	497.33	397.87	298.40	248.67	149.20

[1] From Circular No. 19, U. S. Bureau of Standards, April 1, 1914.

326. TABLES OF CORRECTIONS FOR DETERMINING THE TRUE CAPACITIES OF FLASKS FROM THE WEIGHT OF WATER IN AIR.[1]

(Following data are assumed as approximating ordinary conditions: Observed barometric pressure = 76 cm.; relative humidity = 50 per cent; coefficient of expansion of glass = 0.000025 per degree C.)

INDICATED CAPACITY 50 cc.

Temp. ° C.	Tenths of Degrees.									
	0	1	2	3	4	5	6	7	8	9
15	0.104	0.104	0.105	0.106	0.106	0.107	0.107	0.108	0.109	0.109
16	.110	.111	.111	.112	.113	.113	.114	.115	.116	.116
17	.117	.118	.118	.119	.120	.121	.121	.122	.123	.124
18	.124	.125	.126	.127	.128	.128	.129	.130	.131	.132
19	.132	.133	.134	.135	.136	.137	.137	.138	.139	.140
20	.141	.142	.143	.144	.144	.145	.146	.147	.148	.149
21	.150	.151	.152	.153	.154	.155	.156	.157	.158	.159
22	.160	.161	.162	.163	.164	.165	.166	.167	.168	.169
23	.170	.171	.172	.173	.174	.175	.176	.177	.178	.179
24	.180	.182	.183	.184	.185	.186	.187	.188	.189	.190
25	.192	.193	.194	.195	.196	.197	.199	.200	.201	.202
26	.203	.204	.206	.207	.208	.209	.210	.212	.213	.214
27	.215	.216	.218	.219	.220	.222	.223	.224	.225	.226
28	.228	.229	.230	.232	.233	.234	.236	.237	.238	.240
29	.241	.242	.244							

INDICATED CAPACITY 100 cc.

Temp. ° C.	Tenths of Degrees.									
	0	1	2	3	4	5	6	7	8	9
15	0.207	0.208	0.210	0.211	0.212	0.213	0.215	0.216	0.217	0.219
16	.220	.221	.223	.224	.225	.227	.228	.230	.231	.232
17	.234	.235	.237	.238	.240	.241	.243	.244	.246	.247
18	.249	.250	.252	.253	.255	.257	.258	.260	.261	.263
19	.265	.266	.268	.270	.272	.273	.275	.277	.278	.280
20	.282	.284	.285	.287	.289	.291	.293	.294	.296	.298
21	.300	.302	.304	.306	.308	.310	.311	.314	.315	.317
22	.319	.321	.323	.325	.327	.329	.331	.333	.336	.338
23	.340	.342	.344	.346	.348	.350	.352	.354	.357	.359
24	.361	.363	.365	.368	.370	.372	.374	.376	.379	.381
25	.383	.386	.388	.390	.392	.395	.397	.399	.402	.404
26	.406	.409	.411	.414	.416	.418	.421	.423	.426	.428
27	.431	.433	.436	.438	.440	.443	.446	.448	.451	.453
28	.456	.458	.461	.463	.466	.469	.471	.474	.476	.479
29	.482	.484	.487							

The tables of corrections give for each nominal capacity and observed temperature the amounts to be added to the apparent weight (in air against brass weights) of the water contained by the flask to give the capacity in True Cubic Centimeters at 20° C. Example: Apparent weight of water at 22.3° = 99.68; adding correction 0.325 = 100.005, the actual capacity.

[1] From Circular No. 19, U. S. Bureau of Standards, April 1, 1914.

327. TABLE FOR THE CALIBRATION OF FLASKS TO MOHR'S CUBIC CENTIMETERS.

(This table has been calculated from the data given in U. S. Bureau of Standards Circular No. 19, April, 1914.)

Temp. °C.	Appar- ent Wt. Grams.	Temp. °C.	Appar- ent Wt. Grams.	Temp. °C.	Appar- ent Wt. Grams.	Temp. °C.	Aappr- ent Wt. Grams.
15	100.033	19	99.975	24	99.879	29	99.758
16	100.020	20	99.958	25	99.857	30	99.731
17	100.007	21	99.940	26	99.834	31	99.704
17.5	100.000	22	99.921	27	99.809	32	99.674
18	99.991	23	99.900	28	99.784	33	99.644

Mohr's cubic centimeter or unit is the volume occupied by 1 gram of water as weighed with brass weights in the air at 17.5° C. Flasks graduated to Mohr's cubic centimeter should be used with the normal weight of 26.048 grams. This table is designed to obviate the necessity of making the check calibrations at 17.5° C. (See page 169.)

327a. TABLE SHOWING THE BOILING-POINTS OF SUGAR SOLUTIONS.—(FLOURENO, FREUTZEL.)

SUCROSE SOLUTIONS.

Per Cent Sucrose.	Boiling-point, ° C.	Per Cent Sucrose.	Boiling-point, ° C.
10	100.1	65	103.9
20	100.3	70	105.3
30	100.6	75	107.4
40	101.1	80	110.3
50	101.9	85	114.5
55	102.4	90	122.6
60	103.1		

JUICE, SIRUP AND MOLASSES.

Degree Brix.	BOILING-POINT, ° C.		Degree Brix.	BOILING-POINT, ° C.	
	Juice and Sirup.	Molasses.		Juice and Sirup.	Molasses.
10	100.2	100.3	55	102.8	103.4
20	100.2	100.6	60	103.5	104.2
30	100.8	101.1	65	104.4	105.3
40	101.4	101.7	70	105.8	106.8
50	102.2	102.7	75		

See Table **330.**

328. TABLE SHOWING THE VOLUME OF SUGAR SOLUTIONS AT DIFFERENT TEMPERATURES.—(Gerlach.)

Temp.°C.	10 per cent.	20 per cent.	30 per cent.	40 per cent.	50 per cent.
0°	10000	10000	10000	10000	10000
5	10004.5	10007	10009	10012	10016
10	10012	10016	10021	10026	10032
15	10021	10028	10034	10042	10050
20	10033	10041	10049	10058	10069
25	10048	10057	10066	10075	10088
30	10064	10074	10084	10094	10110
35	10082	10092	10103	10114	10132
40	10101	10112	10124	10136	10156
45	10122	10134	10146	10160	10180
50	10145	10156	10170	10184	10204
55	10170	10183	10196	10210	10229
60	10197	10209	10222	10235	10253
65	10225	10236	10249	10261	10278
70	10255	10265	10277	10287	10306
75	10284	10295	10306	10316	10332
80	10316	10325	10335	10345	10360
85	10347	10355	10365	10375	10388
90	10379	10387	10395	10405	10417
95	10411	10418	10425	10435	10445
1 00	10442	10450	10456	10465	10457

329. TABLE SHOWING THE CONTRACTION OF INVERT SUGAR ON DISSOLVING IN WATER; ALSO, THE CONTRACTION OF CANE-SUGAR SOLUTIONS ON INVERSION.
(From " Manuel Agenda" Gallois and Dupont.)

Per Cent Sugar.	Volume.	Contraction.	SPECIFIC GRAVITY.	
			Cane-Sugar Solution.	Invert-Sugar Solution.
0	1.00000	0.00000	1.0000	1 0000
5	.99863	0.00137	1.0206	1.0206
10	.99744	0.00256	1.0413	1.0418
15	.99639	0.00361	1.0630	1.0631
20	.99546	0.00454	1.0854	1.0856
25	.99462	0.00538	1.1086	1.1086

330. TABLE SHOWING THE BOILING-POINT OF SUGAR SOLUTIONS.—(Gerlach.)

Strength of Solution.	Boiling-point, ° C.	Boiling-point, ° F.
Per cent.		
10	100.4	212.7
20	100.6	213.1
30	101	213.8
40	101.5	214.7
50	102	215.6
60	103	217.4
70	106.5	223.7
80	112	233.6
90.8	130	266

331. TABLE SHOWING THE SOLUBILITY OF LIME IN SOLUTIONS OF SUGAR.

Sugar in 100 parts water.	Density of Sirup.	Density after saturation with lime.	100 PARTS OF THE RESIDUE DRIED AT 120° C. CONTAIN:	
			Lime.	Sugar.
40	1.122	1.179	21	79
35	1.110	1.166	20.5	79 5
30	1.096	1.148	20.1	79.9
25	1.082	1.128	19.8	80.2
20	1.068	1.104	18.8	81.2
15	1.052	1.080	18.5	81.5
10	1.036	1.053	18.1	81.9
5	1.018	1.026	15.3	84.7

332. TABLE SHOWING THE SOLUBILITY OF SUGAR IN WATER.—(AFTER FLOURENS.)

Temp. ° C.	Sugar. Per Cent.	Degree Baumé		Temp. ° C.	Sugar. Per Cent.	Degree Baumé	
		at the observed temperature.	at 15° C.			at the observed temperature.	at 15° C.
0	64.9	35.3	34.6	55	72.8	37.5	39.3
5	65	35.35	34.9	60	74	37.9	39.9
10	65.5	35.45	35.2	65	75	38.3	40.55
15	66	35.5	35.5	70	76.1	38.6	41.1
20	66.5	35.6	35.7	75	77.2	39	41.7
25	67.2	35.8	36.25	80	78.35	39.3	42.2
30	68	36	36.7	85	79.5	39.65	42.8
35	68.8	36.2	37.1	90	80.6	39.95	43.3
40	69.75	36.4	37.5	95	81.6	40 1	43.7
45	70 8	36.75	38.1	100	82.5	40.3	44.1
50	71.8	37.1	38.7				

333. TABLE SHOWING THE SOLUBILITY OF SUGAR IN WATER. (HERZFELD.)

Temp. ° C.	Sugar. Per Cent.	Temp. ° C.	Sugar. Per Cent.	Temp. ° C.	Sugar. Per Cent.
0	64.18	35	69.55	70	76.22
5	64.87	40	70.42	75	77.27
10	65.58	45	71.32	80	78.36
15	66.53	50	72.25	85	79.46
20	67.09	55	73.20	90	80.61
25	67.80	60	74.18	95	81.77
30	67.90	65	75.88	100	82.97

The solubility is decreased by presence of a small quantity of organic or inorganic salts, but increased by a large quantity.

334. TABLE SHOWING THE SOLUBILITY OF SUGAR IN ALCOHOL AT 17.5° C. (OTTO SCHREFELD.)

(Zeit. f. Rübenzucker-Ind., 44, 970.)

Alcohol Per Cent by Weight.	Sucrose Per Cent.	Sucrose in Grams in 100 Grams of the Mixture of Alcohol and Water Solution.
0	66.20	195.8
5*	64.25	179.7
10*	62.20	164.5
15	60.40	152.5
20*	58.55	141.2
25	56.20	128.3
30	54.05	117.8
35	51.25	105.3
40	47.75	91.3
45	43.40	76.6
50	38.55	62.7
55	32.80	48.8
60	26.70	36.4
65	19.50	24.2
70	12.25	13.9
75	7.20	7.7
80	4.05	4.2
85	2.10	2.1
90	0.95	0.09
95	0.15	0.01
Absolute	0.00	0.00

* Calculated.

335. TABLE SHOWING THE SOLUBILITY OF STRONTIA IN SUGAR SOLUTIONS. (SIDERSKY.)

Per Cent Sucrose.	Strontia (SrO) Per Cent of the Solution.				Per Cent Sucrose.	Strontia (SrO) Per Cent of the Solution.			
	At 3° C.	At 15° C.	At 24° C.	At 40° C.		At 3° C.	At 15° C.	At 24° C.	At 40° C.
1	0.45	0.65	0.70	1.68	11	1.30	1.57	2.01	3.75
2	0.53	0.75	0.83	1.89	12	1.38	1.66	2.14	3.96
3	0.62	0.84	0.96	2.09	13	1.47	1.75	2.28	4.16
4	0.70	0.93	1.09	2.30	14	1.55	1.84	2.41	4.37
5	0.79	1.03	1.22	2.51	15	1.64	1.94	2.55	4.58
6	0.87	1.12	1.35	2.72	16	1.72	2.03	2.69	4.79
7	0.96	1.21	1.48	2.92	17	1.81	2.12	2.83	4.99
8	1.04	1.30	1.61	3.13	18	1.90	2.21	2.97	5.20
9	1.13	1.39	1.74	3.33	19	1.99	2.30	3.11	5.41
10	1.21	1.48	1.87	3.55	20	2.08	2.39	3.25	5.61

336. TABLE SHOWING THE SOLUBILITY OF BARYTA IN SUGAR SOLUTIONS.

(PELLET and SENCIER, *La fabrication du sucre*, 1, 186.)

Sucrose per 100 cc.	Baryta (BaO) per 100 cc.	Baryta (BaO) per cent Sucrose.
2 5	4.59	18.3
5	5.46	10.9
7.5	6.56	8 7
10	7.96	7.7
12.5	9.41	7.5
15	10.00	6.6
20	10.90	5.4
25	12.90	5.1
30	14.68	4.9

337. TABLE SHOWING THE SOLUBILITY OF CERTAIN SALTS IN WATER IN THE PRESENCE OF SUCROSE.

(JACOBSTHAL, *Zeit. Rübenzuckerind*, 18, 649; taken from Sidersky's *Traité d'analyse des Matières Sucrées*, p. 11)

Solution containing	5% Sucrose.	10% Sucrose.	15% Sucrose.	20% Sucrose.	25% Sucrose.
	Grams.	Grams.	Grams.	Grams.	Grams.
Sulphate of calcium.	2.095	1.946	1.593	1.539	1.333
Carb. of calcium	0.027	0.036	0.024	0.022	0.008
Oxalate of calcium .	0.033	0.047	0.012	0.008	0.001
Phosph. of calcium .	0 029	0.028	0 014	0.018	0.005
Citrate of calcium...	1.813	1.578	1.505	1.454	1.454
Carb. of magnesium	0.317	0.199	0.194	0.213	0.284

338. TABLE SHOWING THE MORE IMPORTANT CHEMICAL AND PHYSICAL PROPERTIES OF THE CARBOHYDRATES. COMPILED BY ERVIN E. EWELL.

(From von Lippmann's "Chemie der Zuckerarten," second edition; Tollens' "Handbuch der Kohlenhydrate," with reference to original papers.)

Name, Synonyms, and Formulæ.	Melting-point ° C.	Melting-point of Osazone ° C.	Source, etc.
I. MONOSACCHARIDES.			
A. Bioses.			
Glycollic aldehyde...	....	169°–170°	Obtained by oxidation of glycol with nitric acid or reduction of glyoxal with zinc and acetic acid Has not been obtained in a pure state.
$C_2H_4O_2 = CH_2OH.COH.$			
B. Trioses.			
Glycerose...	Sirupy.	181°; 200°	Obtained by oxidization of glycerol with nitric acid or with bromine. A mixture of dioxyacetone and glycerinaldehyde.
$C_3H_6O_3 = CH_2OH.CO.CH_2OH.$			
$C_3H_6O_3 = CH_2OH.CHOH.CHO.$			
C. Tetroses.			
Erythrose...	....	116°–118°	Made from tetrahydric alcohol erythrol (erythrite) by oxidation with nitric acid. Probably mixed with isomeric ketone $CH_2OH.CHOH.CO.CH_2OH.$ Only its osazone has been obtained pure. Erythrol occurs free and combined in lichens and algae.
$C_4H_8O_4 = CH_2OH.(CHOH)_2.CHO.$			
D. Pentoses.			
1. Aldo-pentoses.			
$C_5H_{10}O_5 = CH_2OH.(CHOH)_3.CHO.$			
l-arabinose...	[3]160°; [3]150° [4]130°	160°	Obtained alone or mixed with various other sugars by hydrolysis of gums and other vegetable substances.
arabinose, arabose...			
pectinose, pectin-sugar...			
d-arabinose...	160°	159°–160°	Obtained by synthesis.
i-arabinose...		163°	Obtained by mixing equal weights of l-arabinose and d-arabinose.
xylose...	[5]185°–140° [6]141°; [7]144° [13]145°; [11]154° [9]150°–153°	[11]152°–155° [6]155°; [10]158° [12]160°; [8],[9]161° [5]170°	Obtained alone or mixed with various other sugars by the hydrolysis of gums and other vegetable substances. Its most important source is a wood gum (xylan), extracted from various kinds of wood by means of dilute solutions of caustic alkalies.
wood-sugar...			

i-xylose. Inactive xylose.	......	210°-215°	This name has been given by Fischer to a synthetic sugar of which he prepared the osazone.
2. Keto-pentoses. CH₂OH.(CHOH)₂.CO.CH₂OH.	Sirup.	......	Obtained by the reduction of the lactone of ribonic acid. Not yet known with certainty, but their existence is evidenced by the work of Fischer.
Ribose			
3. Methyl-pentoses. C₆H₁₂O₅=C₅H₉O₅.CH₃.			
Fucose	¹⁴194°-105°	159°	From the seaweed *Fucus nodosus.*
Rhamnose. Isodulcite rhamnodulcite, rhamnegin-sugar, hesperidin-sugar.		180°	Widely distributed in the vegetable kingdom in the form of various glucosides.
Chinovose. C₆H₁₂O₅ = CH₃.(CHOH)₄.CHO.	Sirup.	193°-194°	A decomposition product of chinovite, a constituent of cinchona bark.
E. Hexoses. **1. Aldo-hexoses.** CH₂OH.(CHOH)₄.CHO.			
d-glucose. Dextrose, grape-sugar, starch-sugar.	¹⁴144°-146°	205°-210°	Free and combined in the form of glucosides, gums, and polysaccharides, and in mixtures with various other sugars in a host of vegetable spices and in animal secretions.
l-glucose.	139°-90°	208°	Reduction of the lactone of l-gluconic acid.
i-glucose. Levorotatory glucose. Inactive glucose.	141°-143°	210°-217°	Obtained by mixing equal quantities of d- and l-glucoses.
d-mannose. Mannose, dextrorotatory mannose, isomannitose, seminose.	Sirup.	¹⁴205°-210°	Oxidation of manite; hydrolysis of various vegetable materials.
l-mannose. Levorotatory mannose.		¹⁴208°	Obtained synthetically by reduction of l-mannonic acid.
i-mannose. Inactive mannose.		¹⁴210°-217°	Obtained by the reduction of the lactone of i-mannonic acid.
d-gulose. Dextrorotatory gulose.	Sirup.	......	Obtained by the reduction of d-gulonic acid, which is in turn obtained by the reduction of glycuronic acid or d-saccharic acid.

1 Fischer and Laudsteiner.   2 Scheibler, Lippmann, Conrad, and Guthzeit.   3 Oat.   4 Martin.   5 Bauer.   6 Bertrand.
7 Wheeler and Tollens.   8 Allen and Tollens.   9 Stone and Test.   10 Hébert.   11 Koch.   12 Behrend and Will.
13 Anhydride.   14 Hydrate.   15 The d-, l-, and i-mannoses form d-, l-, and i-glucosazones, respectively.

TABLE SHOWING THE MORE IMPORTANT PROPERTIES OF THE CARBOHYDRATES.—*Continued.*

Name, Synonyms, and Formulae.	Melting-point ° C.	Melting-point of Osazone ° C.	Source, etc.
l-gulose	Sirup.	156°	Obtained synthetically by the reduction of l-gulonic acid.
i-gulose		157°	Obtained by the reduction of i-gulonic acid.
d-idose			Obtained by the reduction of d-idonic acid, which is obtained by heating d-gulonic acid with pyridin. Yields same osazone as d-gulose.
l-idose			Obtained from l-gulonic acid in same manner that d-gulonic acid yields d-idose.
i-idose	161°-170°	193°-197°	Existence of i-idose is reported by Fischer.
d-galactose			Rarely reported free in nature, but is widely distributed in combination. It is obtained pure or mixed by the hydrolysis of milk sugar, various glucosides and polysaccharides.
galactose, dextrorotatory galactose	118°-120°		
l-galactose	162°-163°	192°-195°	Obtained synthetically.
i-galactose	140°-144°	206°	Obtained synthetically.
d-talose	Sirup.		Obtained synthetically. Bears same relation to d-galactose that d-mannose bears to d-glucose. Forms d-galactosazone.
l-talose			Only the derivative l-talomucic acid is known.
i-talose			Only the derivative i-tallite is known.
Chitose			Obtained by hydrolysis of chitin, a substance found in wing-cases of insects, etc. Found in plants.
2. *Keto-hexoses.* $CH_2OH.(CHOH)_3.CO.CH_2OH.$			
d-fructose, levulose, fruit-sugar, chylariose.	95°-105°		Widely distributed both free and combined as a constituent of various polysaccharides. Forms d-glucosazone.
l-fructose.			Obtained synthetically from l-glucosazone. With 2 mol. phenylhydrazine forms l-glucosazone.
i-fructose. Inactive fructose, i-levulose, α-acrose.	Sirup.		Obtained synthetically from acrolein. With 2 molecules phenylhydrazine forms i-glucosazone.

Name			Source / Notes
Sorbinose. Sorbose, sorbine.	....	....	Juice of mountain-ash berries.
Formose.		164°	Obtained by condensation of formic aldehyde. Decomposes on heating to 90°–110° C.
Methose.		144°	Obtained by condensation of formic aldehyde.
3. Hexoses of unknown nature and constitution, $C_6H_{12}O_6$.			
(a) Natural sugars	Sirup.	204°–206°	*Chondroglucose*, from chondrin by treatment with hydrochloric acid. *Crocose* by hydrolysis of coloring matter of saffron. *Eucalin*, from melitose by hydrolysis. *Urine-sugar*, from diabetic urine. *Hederose*, a decomposition product of a glucoside found in the ivy (*Hedera helix*). *Indiglucin*, from the hydrolysis of indican; probably identical with dextrose. *Locoose*, from the hydrolysis of Chinese green, a coloring matter from a species of Rhamnus. *Paraglucose*, formed in the vinous fermentation of cane-sugar. *Phlorose*, from the hydrolysis of phloridzin. *Scammonose*, from the hydrolysis of a glucoside of scammony. *Skimminose*, from the hydrolysis of skimmin, a constituent of a certain Japanese species of rue. *Solanose*, from hydrolysis of solanin. *Trefilose*, forms 5 to 6 per cent of the milk of the Egyptian buffalo cow. *Wine sugar*, from many natural wines.
(b) Synthetic sugars	....	....	β-acrose, only known in form of osazone. Melting-point of osazone 158°–159°. β-formose (pseudoformose, isoformose) obtained by condensation of formic aldehyde. Melting-point of osazone 148° C.
4. Methyl-hexoses.			
α-rhamno-hexose. $CH_3.(CHOH)_4.COH$.	180°		Obtained synthetically.
β-rhamnus-hexose.		200°	Obtained synthetically.
Digitalose. $C_7H_{14}O_6$.	Sirup.	200°	Hydrolysis of the glucoside digitalin.
F. Heptoses.			
α-gluco-heptose. $CH_2OH.(CHOH)_5.CHO$.	180°–190°	198°	Obtained synthetically.
β-gluco-heptose. $CH_2OH.(CHOH)_5.CHO$.	Sirup.		Obtained synthetically. Forms α-glucoheptosazone.

¹ Anhydride.   ² Hydrate.

TABLE SHOWING THE MORE IMPORTANT PROPERTIES OF THE CARBOHYDRATES.—*Continued.*

Name, Synonyms, and Formulæ.	Melting-point ° C.	Melting-point of Osazone ° C.	Source, etc.
d-manno-heptose	134°	200°	Obtained synthetically. Formula, $C_7H_{14}O_7$.
l-manno-heptose	Sirup.	203°	Obtained synthetically. Formula, $C_7H_{14}O_7$.
d-manno-heptose	Sirup.	210°	Obtained synthetically. Formula, $C_7H_{14}O_7$.
a-gala-heptose		220°	Obtained synthetically.
β-gala-heptose	Sirup.		Obtained synthetically.
Rhamno-heptose		200°	Obtained synthetically. A methyl-heptose.
$CH_3 \cdot (CHOH)_6 \cdot CHO$			
G. OCTOSES. $C_8H_{16}O_8$.			
a-gluco-octose		210°–212°	Obtained synthetically. Hydrated $= C_8H_{16}O_8 + 2H_2O$. Melting-point 98°.
β-gluco-octose			Obtained synthetically.
d-manno-octose	Sirup.	228°	Obtained synthetically.
Gala-octose			Obtained synthetically.
Rhamno-octose		216°	Obtained synthetically. A methyl-octose.
H. NONOSES. ($C_9H_{18}O_9$.)			
a-gluco-nonose	Sirup.	280°–288°	Obtained synthetically.
d-gluco-nonose	180°	217°	Obtained synthetically.
II. DISACCHARIDES.			
A. DERIVATIVES OF PENTOSES.			
Arabinon (di-arabinose). $C_{10}H_{18}O_9$.			Arabinic acid (metapectic acid).
B. DERIVATIVES OF HEXOSES.			
Sucrose	160°		Very widely distributed in the vegetable kingdom. Sucrose, when free from raffinose, is not browned at 120°–125°.
Saccharose, cane-sugar.			
Trehalose	200°		From ergot and other fungi. The hydrate, $C_{12}H_{22}O_{11} + H_2O$ melts at 130°, becomes anhydrous, solidifies, and again melts at 200°. Forms no osazone.
$C_{12}H_{22}O_{11}$.			
Mycose, trehalose.			
Lactose	200°		From the milk of various mammals. The hydrate, $C_{12}H_{22}O_{11} + H_2O$ can be dried at 100° and at 145°–150° begins to lose water and decomposes.
Milk sugar, lactobiose.			

Maltose. Maltobiose, ptyalose, cerealose.	208°	From starch by the action of diastase and by the action of ptyalin. The hydrate, $C_{12}H_{22}O_{11}$,H_2O, loses its water at 100°-105° in vacuo, at 100° to 110° in the air with browning,
Isomaltose.	150°-153°	From malted grain. Begins to decompose at 200°, with marked decomposition at 200°.
Melibiose.	176°-178°	Formed, together with d-fructose, by careful inversion of melitriose.
Turanose.	215°-220°	Formed, together with d-glucose, by careful inversion of [melitriose].
Cyclanose.		From cyclamen tubers.
Agavose.		From the juice of the agave.
Para-saccharose.		Formed by the action of a certain yeast plant on cane-sugar in the presence of ammonium phosphate.
C. DERIVATIVES OF HEPTOSES. $C_{13}H_{24}O_{12}$.		Obtained synthetically from a milk-sugar derivative.
III. TRISACCHARIDES. $C_{18}H_{32}O_{16}$.		
Raffinose. Melitriose, gossypose, cotton-sugar.		Beet-molasses, cotton-seed, eucalyptus manna, etc. Recently reported in cane-molasses. The hydrate ($C_{18}H_{32}O_{16} + 5H_2O$) loses its water on careful heating to 80°, then to 100°-105°; heated quickly it melts below 100°, losing part of its water of crystallization; decomposition begins at 125°-130°
Melecitose Melecitriose.	148°-150°	Manna of Pinus larix. The hydrate ($C_{18}H_{32}O_{16} + 2H_2O$) loses its water on gradual heating; the anhydrous residue melts at 148°-150°.
Stachyose.		Tubers of Stachys tuberifera.
Gentianose.	210°	From the roots of Gentiana lutea.
Lactosinose. Lactosin.		From the roots of Silene vulgaris and other members of the order Caryophyllaceae.
Secalose.		From unripe rye.
A sugar of the formula $C_{18}H_{32}O_{16}$.	150°-153°	Formed together with d-glucose by the action of diastase on [starch at a high temperature.
IV. POLYSACCHARIDES. Starch ($C_6H_{10}O_5$)x.		Polysaccharides include soluble starch, dextrin, inulin, the galactans, and a number of plant constituents that are transformed into mono-saccharides by hydrolysis with dilute acids. Very widely distributed in the vegetable kingdom.

TABLE SHOWING THE MORE IMPORTANT PROPERTIES OF THE CARBOHYDRATES.—Continued.

Name.	Specific Rotatory Power, $(\alpha)_D$.	Behavior with Alkaline Copper Sol.	Behavior with Yeast.	Oxidation Products.	Reduction Products.
I. MONOSACCHARIDES.					
A. Bioses.					
Glycollic aldehyde.....	......	*	......	First glycollic then oxalic acid.	
B. Trioses.					
Glycerose..	......	R.R.T.	Readily fermented.	First glyceric then tartaric acid.	
C. Tetroses.					
Erythrose....	Osazone inactive.	S.R.	......	First erythritic then tartaric acid.	
D. Pentoses.					
1. *Aldo-pentoses*....		{ R.	Not fermented by yeast. Fermentable by *Bacillus æthaceticus.*	{ By gentle oxidization, arabonic acid; more vigorous oxid., *l*-trioxyglutaric ac.	Arabite.
l-arabinose.......	{ ¹104.4° at 18° / ²105.4° at 20° / ²105.1°				
d-arabinose.......	−104.1°	R.	......	*d*-trioxyglutaric acid.	
i-arabinose.......	Inactive!				
Xylose	See foot-note 4.	R.	Not fermented.	Xylo-trioxyglutaric and trioxybutyric acid.	Xylite.
i-xylose.	Inactive.				
Ribose....				......	Adonite.
2. *Keto-pentoses.*					
3. *Methyl pentoses.*					
Fucose..	−7°	R.	Unfermentable	*l*-trioxyglutaric, carbonic, formic, and oxalic acids.	Rhamnite.
Rhamnose.......	88°-9°	R.			
Chinovose....	......	S.R.			
E. Hexoses.					
1. *Aldo-hexoses.*					
d-glucose.......	See foot-note 6.	R.	Fermentable.	*d*-gluconic acid by action of Br or Cl; by HNO₃, saccharic acid.	*d*-sorbite.
l-glucose...	−51.4° in 4% sol.	......	Unfermentable.		

	Rotation		Fermentation	Oxidation products	Reduction products
i-glucose........	Inactive.		Half fermented, the l-glucose remaining. Fermentable.	First i-gluconic then i-saccharic acid.	
d-mannose........	12.89°-14.36° at 20°	R.	Fermentable.	d-mannonic acid by Br or HNO₃; further with HNO₃, d-manno-saccharic acid.	d-mannite (mannitol).
l-mannose........	Levorotatory.	R.	Unfermentable.		l-mannite.
i-mannose........	Inactive.	R.	Is half fermented, the l-mannose remaining. Unfermentable.	i-mannonic acid, with Br.	i-mannite.
d-gulose........	Weakly dextro-rotatory.		Unfermentable.	d-saccharic acid.	d-sorbite.
l-gulose........	....		Unfermentable.	First l-gulonic then l-sac-charic acid.	l-sorbite.
l-idose........			......	First l-idonic then ido-saccharic acid.	
d-galactose........	See foot-note 7.	R.	Fermentable.	With Cl or Br, d-galactonic acid; with HNO₃, mucic acid.	Dulcite with other alcohols.
l-galactose........	-73.6° to -74.6°		Unfermentable.	First l-galactonic then mu-cic acid.	Dulcite.
i-galactose........	Inactive.		Is half fermented. l-galactose remaining. Unfermentable.		
d-talose........	....		Unfermentable.	First d-talonic then d-talo-mucic acid.	d-talite.
Chitose........	Dextrorrotatory.	R.			

*R.R.T. = reduces at room temperature; R. = reduces; S.R. = strongly reducing; N.R. = no reduction.
[1] Scheibler. [2] Lippmann. [3] Killani.
[4] Rotatory power increases with the concentration; $(\alpha)_D = 18.425°$ when $c=9$; $(\alpha)_D = 28.702°$ when $c=61.7$ (Tollens and Schulze).
[5] Fischer and Piloty.
[6] According to Tollens: 10% sol. of hydrate, $(\alpha)_{D}^{20} = 47.92°$; 10% sol. of anhydride, $(\alpha)_{D}^{20} = 52.74°$. The rotatory power increases with the concentration, and is indicated by the following formulæ: For hydrate, $(\alpha)_{D}^{20} = 47.78 + .015584p + .0009888p^2$;

For anhydride, $(\alpha)_{D}^{20} = 52.5 + .018799p + .00051669p^2$;

p = per cent d-glucose by weight of the solution.

[7] According to Rindell and Meisel, when $t = 10°$ to $80°$ and $p = 4.89\%$ to 35.86%, $(\alpha)_D = 88.888 + .0785p - .209t$. t = temp.

TABLE SHOWING THE MORE IMPORTANT PROPERTIES OF THE CARBOHYDRATES.—*Continued.*

Name.	Specific Rotatory Power, $(\alpha)_D$.	Behavior with Alkaline Copper Sol.	Behavior with Yeast.	Oxidation Products.	Reduction Products.
2. *Keto-hexoses.*					
d-fructose	See foot-note 1.	R.	Fermentable.	A mixture of formic, glycollic and trioxybutyric acids.	d-mannite and d-sorbite.
l-fructose	Dextrorotatory.	...	Unfermentable.	...	i-mannite (acrite).
i-fructose	Inactive.	R.	Is half fermented, the l-fructose remaining.		
Sorbinose	−43.4°	R.	Unfermentable.	Aposorbonic and other acids.	d-sorbite.
Formose	Inactive.	R.	Unfermentable.		
Methose		R.	Fermentable.		
3. *Hexoses* of unknown nature and constitution	See foot-note 2.				
(a) Natural sugars.					
(b) Synthetic sugars.					
β-formose	Inactive.	R	Unfermentable.		
4. *Methyl-hexoses.*					
a-rhamno-hexose	−61.4° at 20°		Unfermentable.	Mucic acid. l-talomucic acid.	a-rhamnohexite.
β-rhamno-hexose	−79.4° at 28°				
Digitalose					
F. HEPTOSES.					
a-gluco-heptose	−19.7° at 20°, 10 gms. in 100 cc.		Not readily fermented.		a-gluco-heptite.
d-manno-heptose	68.64° at 20°		Unfermentable.		d-manno-heptite.
l-manno-heptose			Unfermentable.		l-manno-heptite.
i-manno-heptose				Inactive pentoxypimelinic acid.	i-manno-heptite.
a-gala-heptose					
β-gala-heptose				Active pentoxypimelinic acid.	

				Hydrolysis Products.
Rhamno-heptose ..	8.4° at 20°		Unfermentable.	a-gluco-octite.
G. OCTOSES.				
a-gluco-octose	[3] −48.9° at 20°, [4] −50.5° at 20°, −8.3°(ca) at 20°		Unfermentable.	d-manno-octite.
d-manno-octose		R.		a-gluco-nonite.
Rhamno-heptose	Weakly dextrorotatory. 50°(ca) at 20°		Unfermentable.	
H. NONOSES.				
a-gluco-nonose			Fermentable.	
d-manno-nonose				
II. DISACCHARIDES.				Hydrolysis Products.
A. DERIVATIVES OF PENTOSES.				
Arabinon	198.8°	R.		l-arabinose.
B. DERIVATIVES OF HEXOSES				
Sucrose	See foot-note 5.	N.R.	Fermentable.	Various acids according to conditions. / d-glucose. d-fructose.

[1] (α)$\frac{20}{D}$ (25 grams in 100 cc. of solution) = − 91.8°. The specific rotatory power diminishes as the temperature increases, and increases with the concentration.

[2] Chondroglucose, (α)$_D$ = − 45.8° ; crocose, dextrorotatory ; eucalyn, (α)$_j$ = 65° ; urine-sugar, (α)$_D$ = − 26.0° ; hederose, (α)$_D$ = 98.88° ; locaose, inactive ; paraglucose, (α)$_j$ = 40° ; phlorose, (α)$_D$ = 39° to 41° ; scammonose, (α)$\frac{19}{D}$ = 17.78° ; skimminose, (α)$_D$ = 24° ; solanose, (α)$\frac{20}{D}$ = 28.6° ; tewflkose, (α)$_D$ = 48.7°. All reduce copper except skimminose (?), and wine-sugar. Eucalyn, hederose, and wine-sugar are unfermentable, and scammonose is fermentable. On oxidation eucalyn yields oxalic acid.

[3] Hydrate.   [4] Anhydride.   [5] Sucrose in 4% solution, (α)$\frac{20}{D}$ = 66.8; 70% solution, (α)$\frac{20}{D}$ = 65.5° (Tollens).

TABLE SHOWING THE MORE IMPORTANT PROPERTIES OF THE CARBOHYDRATES.—Continued.

Name.	Specific Rotatory Power, $(\alpha)_D$	Behavior with Alkaline Copper Sol.	Behavior with Yeast.	Oxidation Products.	Hydrolysis Products.
Trehalose................	197.28°.	....	Unfermentable.	Forms oxalic acid on heating with dilute HNO_3.	d-glucose.
Lactose................	132.58° at 20° for hydrate.	R.	No true alcoholic fermentation.	Mucic and other acids according to conditions.	d-glucose and d-galactose.
Maltose................	137° at 20° in 11% sol.	R.	Fermentable.	d-saccharic acid on treatment with HNO_3.	d-glucose.
Isomaltose............	139°-140°	R.	Hydrolysis followed by fermentation.	....	d-glucose.
Melibiose............	127.3°-189°	R.	....	....	{ d-glucose and d-galactose.
Turanose............	65°-68°	R.	Ferments with difficulty or not at all.	....	d-glucose.
Cyclamose......	−15.15°	R.	Unfermentable.	....	Not determined.
Agavose	Inactive $(\alpha)_j = 108°$	R.		....	Not determined.
Para-saccharose...	....		....	....	{ d-galactose and d-glucoheptose.
C. DERIVATIVES OF HEPTOSES.					
Sugar of the formula $C_{18}H_{24}O_{12}$	....	....	....	....	....
III. TRISACCHARIDES.					
Raffinose	105°-105.7°.	N.R.	Fermentable.	With HNO_3, oxalic, saccharic, and mucic acids.	First d-fructose and mellbiose; further action decomposes the latter into d-glucose and d-galactose.

			Unfermentable.		
Melecitose	88.65°–88.8° for anhydride.	N.R.			First d-glucose and turanose; further action decomposes the latter into d-glucose.
Stachyose	147.9°–148.1° for anhydride.	N.R.		Mucic and other acids.	d-galactose, d-glucose, and d-fructose.
Gentianose	65.7°				
Lactosinose	211.7° at 16°			Mucic acid.	d-galactose and two other sugars.
Secalose	–28.6° to –28.9°				d-fructose.
A sugar of the formula $C_{18}H_{33}O_{16}$	148°	R.	Ferments with difficulty or not at all.		d-glucose.
IV. POLYSACCHARIDES.					
Starch					d-glucose, maltose, dextrine, isomaltose, according to conditions.

[1] Schmoeger.

339. FREEZING MIXTURES.—(Walker's List.)

Parts	Centigrade.	Fahrenheit.	Réaumur.
	Temperature Falls—		
Ammonium Nitrate... 1 Water.... 1	From + 4°.4 to − 15°.5	From + 40° to + 4°	From + 3°.5 to −12°.4
Ammonium Chloride.. 5 Potassium Nitrate .... 5 Water 16	From + 10° to − 12°.2	From + 50° to + 10°	From + 8° to − 9°.3
Ammonium Chloride.. 5 Potassium Nitrate .... 5 Sodium Sulphate...... 8 Water 10	From + 10° to − 15°.5	From + 50° to + 4°	From + 8° to −12°.4
Sodium Nitrate .... 3 Nitric Acid, diluted.... 2	From + 10° to − 19°.4	From + 50° to − 3°	From + 8° to −15°.5
Ammonium Nitrate... 1 Sodium Carbonate.... 1 Water................. 1	From + 10° to − 21°.7	From + 50° to − 7°	From + 8° to −17°.3
Sodium Phosphate ... 9 Nitric Acid, diluted... 4	From + 10° to − 24°.4	From + 50° to − 12°	From + 8° to −19°.5
Sodium Sulphate...... 5 Sulphuric Acid, dilut.. 4	From + 10° to − 16°.1	From + 50° to + 3°	From + 8° to −12°.9
Sodium Sulphate.,.... 6 Ammonium Chloride.. 4 Potassium Nitrate.... 2 Nitric Acid, diluted... 4	From + 10° to − 23°.3	From + 50° to − 10°	From + 8° to −18°.6
Sodium Sulphate...... 6 Ammonium Nitrate... 5 Nitric Acid, diluted... 4	From + 10° to − 40°	From + 50° to − 40°	From + 8° to − 32°
Snow or pounded ice.. 2 Sodium Chloride (common salt) 1	to − 20°.5	to − 5°	to − 16°.4
Snow or pounded ice.. 5 Sodium Chloride (common salt) .... 2 Ammonium Chloride . 1	to − 24°.4	to − 12°	to − 19°.5
Snow or pounded ice. 21 Sodium Chloride (common salt) ....10 Ammonium Chloride.. 5 Potassium Nitrate ..., 5	to − 27°.7	to − 18°	to − 22°.2
Snow or pounded ice..12 Sodium Chloride (common salt). . ... 5 Ammonium Nitrate... 5	to − 31°.6	to − 25°	to − 25°.3
Snow.... .... 3 Sulphuric Acid, dilu'd 2	From 0° to − 30°.5	From + 32° to − 23°	From 0° to − 24°.4
Snow .... 8 Hydrochloric Acid.... 5	From 0° to − 32°.8	From + 32° to − 27°	From 0° to − 26°.2
Snow .... 7 Nitric Acid, diluted... 4	From 0° to − 34°.4	From + 32° to − 30°	From 0° to − 27°.5
Snow.... .... 4 Calcium Chloride (Chloride of Lime).. 5	From 0° to − 40°	From + 32° to − 40°	From 0° to − 32°
Snow.... .... 2 Calcium Chloride, crystallized 3	From 0° to − 45°.5	From + 32° to − 50°	From 0° to − 36°.4
Snow................. 3 Potash 4	From 0° to − 46°.1	From + 32° to − 51°	From 0° to − 36°.9

340. TABLE SHOWING THE STRENGTH OF SULPHURIC ACID (OIL OF VITRIOL) OF DIFFERENT DENSITIES, AT 15° CENTI GRADE.—(OTTO'S TABLE.)

Per Cent of H₂SO₄.	Specific Gravity.	Per Cent of SO₃.	Per Cent of H₂SO₄.	Specific Gravity.	Per Cent of SO₃.
100	1.8426	81 63	50	1.3980	40.81
99	1.8420	80.81	49	1.3866	40.00
98	1.8406	80.00	48	1.3790	39.18
97	1.8400	79.18	47	1.3700	38.36
96	1 8384	78 36	46	1.3610	37.55
95	1.8376	77.55	45	1.3510	36.73
94	1.8356	76.73	44	1.3420	35.82
93	1.8340	75.91	43	1.3330	35.10
92	1.8310	75.10	42	1.3240	34.28
91	1.8270	74.28	41	1.3150	33.47
90	1.8220	73.47	40	1.3060	32.65
89	1.8100	72.65	39	1.2976	31.83
88	1.8090	71.83	38	1.2890	31.02
87	1.8020	71 02	37	1.2810	30.20
86	1.7940	70.10	36	1.2720	29.38
85	1.7860	69.38	35	1.2640	28.57
84	1.7770	68.57	34	1.2560	27.75
83	1.7670	67.75	33	1.2476	26.94
82	1.7560	66.94	32	1.2390	26.12
81	1.7450	66.12	31	1.2310	25.30
80	1.7340	65.80	30	1.2230	24.49
79	1.7220	64.48	29	1.2150	23.67
78	1.7100	63.67	28	1.2066	22.85
77	1.6980	62.85	27	1.1980	22.03
76	1.6860	62.04	26	1.1900	21.22
75	1.6750	61.22	25	1.1820	20.40
74	1.6630	60.40	24	1.1740	19.58
73	1.6510	59.59	23	1.1670	18 77
72	1.6390	58.77	22	1.1590	17.95
71	1.6270	57.95	21	1.1516	17.14
70	1.6150	57.14	20	1.1440	16.32
69	1.6040	56.32	19	1.1360	15.51
68	1.5920	55.59	18	1.1290	14.69
67	1.5800	54.69	17	1.1210	13.87
66	1.5860	53.87	16	1.1136	13.06
65	1.5570	53.05	15	1.1060	12.24
64	1.5450	52.22	14	1.0980	11.42
63	1.5340	51.42	13	1.0910	10.61
62	1.5230	50.61	12	1.0830	9.79
61	1.512)	49.79	11	1.0756	8.98
60	1.5010	48.98	10	1.0680	8.16
59	1.4900	48.16	9	1.0610	7.34
58	1.4800	47.34	8	1.0536	6.53
57	1.4690	46.53	7	1.0464	5.71
56	1.4596	45.71	6	1.0390	4.89
55	1.4480	44.89	5	1.0320	4.08
54	1.4380	44.07	4	1.0256	3.26
53	1.4280	43.26	3	1.0190	2.44
52	1.4180	42.45	2	1.0130	1.68
51	1.4080	41.63	1	1.0064	0.81

341. ANTHON'S TABLE FOR THE DILUTION OF SULPHURIC ACID.

To 100 parts of Water at 15° to 20° C. add...parts of Sulphuric Acid of 1.84 Specific Gravity.	Specific Gravity of diluted Acid.	To 100 parts of Water at 15° to 20° C. add...parts of Sulphuric Acid of 1.84 Specific Gravity.	Specific Gravity of diluted Acid.	To 100 parts of Water at 15° to 20° C. add...parts of Sulphuric Acid of 1.84 Specific Gravity.	Specific Gravity of diluted Acid.
1	1.009	130	1.456	370	1.723
2	1.015	140	1.473	380	1.727
5	1.035	150	1.490	390	1.730
10	1.060	160	1.510	400	1.733
15	1.090	170	1.530	410	1.737
20	1.113	180	1.543	420	1.740
25	1.140	190	1.556	430	1.743
30	1.165	200	1.568	440	1.746
35	1.187	210	1.580	450	1.750
40	1.210	220	1.593	460	1.754
45	1.229	230	1.606	470	1.757
50	1.248	240	1.620	480	1.760
55	1.265	250	1.630	490	1.763
60	1.280	260	1.640	500	1.766
65	1.297	270	1.648	510	1.768
70	1.312	280	1.654	520	1.770
75	1.326	290	1.667	530	1.772
80	1.340	300	1.678	540	1.774
85	1.357	310	1.689	550	1.776
90	1.372	320	1.700	560	1.777
95	1.386	330	1.705	580	1.778
100	1.398	340	1.710	590	1.780
110	1.420	350	1.714	600	1.782
120	1.438	360	1.719		

342. TABLE SHOWING THE STRENGTH OF NITRIC ACID (HNO_3) BY SPECIFIC GRAVITY. HYDRATED AND ANHYDRIDE.

TEMPERATURE 15°.

(Fresenius, Zeitschrift f. analyt. Chemie. 5. 449.)

Sp. Gr. at 15° C.	100 PARTS CONTAIN—		Sp. Gr. at 15° C.	100 PARTS CONTAIN—	
	N_2O_5	NO_3H		N_2O_5	NO_3H
1.530	85.71	100.00	1.488	75.43	88.00
1.530	35.57	99.84	1.486	74.95	87.45
1.530	85.47	99.72	1.482	73.86	86.17
1.529	85.30	99.52	1.478	72.86	85.00
1.528	83.90	97.89	1.474	72.00	84.00
1.520	83.14	97.00	1.470	71.14	83.00
1.516	82.28	96.00	1.467	70.28	82.00
1.514	81.66	95.27	1.463	69.39	80.96
1.509	80.57	94.00	1.460	68.57	80.00
1.506	79.72	93.01	1.456	67.71	79.00
1.503	78.85	92.00	1.451	66.56	77.66
1.499	78.00	91.00	1.445	65.14	76.00
1.495	77.15	90.00	1.442	64.28	75.00
1.494	76.77	89.56	1.438	63.44	74.01

TABLE SHOWING THE STRENGTH OF NITRIC ACID.—*Continued.*

Sp. Gr. at 15° C.	100 PARTS CONTAIN—		Sp. Gr. at 15° C.	100 PARTS CONTAIN—	
	N_2O_5	NO_3H		N_2O_5	NO_3H
1.435	62.57	78.00	1.295	39.97	46.64
1.432	62.05	77.39	1.284	38.57	45.00
1.429	61.06	71.24	1.274	37.31	43.53
1.423	60.00	69.96*	1.264	36.00	42.00
1.419	59.31	69.20	1.257	35.14	41.00
1.414	58.29	68.00	1.251	34.28	40.00
1.410	57.43	67.00	1.244	33.43	39.00
1.405	56.57	66.00	1.237	32.53	37.95
1.400	55.77	65.07	1.225	30.86	36.00
1.395	54.85	64.00	1.218	29.29	35.00
1.393	54.50	63.59	1.211	29.02	33.86
1.386	53.14	62.00	1.198	27.43	32.00
1.381	52.46	61.21	1.192	26.57	31.00
1.374	51.43	60.00	1.185	25.71	30.00
1.372	51.06	59.59	1.179	24.85	29.00
1.368	50.47	58.88	1.172	24.00	28.00
1.363	49.71	58.00	1.166	23.14	27.00
1.358	48.86	57.00	1.157	22.04	25.71
1.353	48.06	56.10	1.138	19.71	23.00
1.346	47.14	55.00	1.120	17.14	20.00
1.341	46.29	54.00	1.105	14.97	17.47
1.339	46.12	53.81†	1.089	12.85	15.00
1.335	45.40	53.00	1.077	11.14	13.00
1.331	44.85	52.33	1.067	9.77	11.41
1.323	43.70	50.99	1.045	6.62	7.22
1.317	42.83	49.97	1.022	3.42	4.00
1.312	42.00	49.00	1.010	1.71	2.00
1.304	41.14	48.00	0.999	0.00	0.00
1.298	40.44	47.18			

* Formula: $NO_3H + 1\frac{1}{2}H_2O$.   † Formula: $NO_3H + 3H_2O$.

343. TABLE SHOWING THE AMOUNT OF CaO IN MILK OF LIME OF VARIOUS DENSITIES AT 15° C.

(FROM BLATNER'S TABLE.)

Deg. Brix.	Degree Baumé.	Weight of one litre, Milk of Lime.	CaO per litre.	Per Cent CaO.	Deg. Brix.	Degree Baumé.	Weight of one litre, Milk of Lime.	CaO per litre.	Per Cent CaO.
		Grams.	Grams.				Grams.	Grams.	
1.8	1	1007	7.5	0.745	29	16	1125	159	14.13
3.6	2	1014	16.5	1.64	30.8	17	1134	170	15
5.4	3	1022	26	2.54	32.7	18	1142	181	15.85
7.2	4	1029	36	3.5	34.6	19	1152	193	16.75
9	5	1037	46	4.43	36.4	20	1162	206	17.72
10.8	6	1045	56	5.36	38.3	21	1171	218	18.61
12.6	7	1052	65	6.18	40.1	22	1180	229	19.4
14.4	8	1060	75	7.06	42	23	1190	242	20.34
16.2	9	1067	84	7.87	43.9	24	1200	255	21.25
18	10	1075	94	8.74	45.8	25	1210	268	22.15
19.8	11	1083	104	9.6	47.7	26	1220	281	23.03
21.7	12	1091	115	10.54	49.6	27	1231	295	23.96
23.5	13	1100	126	11.45	51.5	28	1241	309	24.9
25.3	14	1108	137	12.35	53.5	29	1252	324	25.87
27.2	15	1116	148	13.26	55.4	30	1263	339	26.84

344. TABLE SHOWING THE AMOUNT OF CaO IN MILK OF LIME OF VARIOUS DENSITIES.—(Mategczek.)

Degree Brix.	Degree Baumé.	1 kilo CaO per..litres Milk of Lime.	Degree Brix.	Degree Baumé.	1 kilo CaO per..litres Milk of Lime.
18	10	7.50	38.3	21	4.28
20	11	7.10	40.2	22	4.16
21.7	12	6.70	42.0	23	4.05
23.5	13	6.30	43.9	24	3.95
25.3	14	5.88	45.8	25	3.87
27.2	15	5.50	47.7	26	3.81
29	16	5.25	49.6	29	3.75
30.9	17	5.01	51.6	28	3.70
32.7	18	4.80	53.5	29	3.65
34.6	19	4.68	55.5	30	3.60
36.5	20	4.42			

345. TABLE SHOWING THE STRENGTH OF HYDROCHLORIC ACID (Muriatic Acid) SOLUTIONS.

TEMPERATURE, 15° C.

(Graham-Otto's Lehrb. d. Chem. 3 Aufl. II. Bd. 1. Abth. p 382.)

Sp. Gr	HCl.	Cl.	Sp. Gr.	HCl.	Cl.	Sp. Gr.	HCl.	Cl.
1.2000	40.777	39.675	1.1328	26.913	26.186	1.0657	13.456	13.094
1.1982	40.369	39.278	1.1308	26.505	25.789	1.0637	13.049	12.697
1.1964	39.961	38.882	1.1287	26.098	25.392	1.0617	12.641	12.300
1.1946	39.554	38.485	1.1267	25.690	24.996	1.0597	12.233	11.903
1.1928	39.146	38.089	1.1247	25.282	24.599	1.0577	11.825	11.506
1.1910	38.738	37.692	1.1226	24.874	24.202	1.0557	11.418	11.109
1.1893	38.330	37.296	1.1206	24.466	23.805	1.0537	11.010	10.713
1.1875	37.923	36.900	1.1185	24.058	23.408	1.0517	10.602	10.316
1.1857	37.516	36.503	1.1164	23.650	23.012	1.0497	10.194	9.919
1.1846	37.108	36.107	1.1143	23.242	22.615	1.0477	9.786	9.522
1.1822	36.700	35.707	1.1123	22.834	22.218	1.0457	9.379	9.126
1.1802	36.292	35.310	1.1102	22.426	21.822	1.0437	8.971	8.729
1.1782	35.884	34.913	1.1082	22.019	21.425	1.0417	8.563	8.332
1.1762	35.476	34.517	1.1061	21.611	21.028	1.0397	8.155	7.935
1.1741	35.068	34.121	1.1041	21.203	20.632	1.0377	7.747	7.538
1.1721	34.660	33.724	1.1020	20.796	20.235	1.0357	7.340	7.141
1.1701	34.252	33.328	1.1000	20.388	19.837	1.0337	6.982	6.745
1.1681	33.845	32.931	1.0980	19.980	19.440	1.0318	6.524	6.348
1.1661	33.437	32.535	1.0960	19.572	19.044	1.0298	6.116	5.951
1.1641	33.029	32.136	1.0939	19.165	18.647	1.0279	5.709	5.554
1.1620	32.621	31.746	1.0919	18.757	18.250	1.0259	5.301	5.158
1.1599	32.213	31.343	1.0899	18.349	17.854	1.0239	4.893	4.762
1.1578	31.805	30.946	1.0879	17.941	17.457	1.0220	4.486	4.365
1.1557	31.398	30.550	1.0859	17.534	17.060	1.0200	4.078	3.968
1.1537	30.990	30.158	1.0838	17.126	16.664	1.0180	3.670	3.571
1.1515	30.582	29.757	1.0818	16.718	16.267	1.0160	3.262	3.174
1.1494	30.174	29.361	1.0798	16.310	15.870	1.0140	2.854	2.778
1.1473	29.767	28.964	1.0778	15.903	15.474	1.0120	2.447	2.381
1.1452	29.359	28.567	1.0758	15.494	15.077	1.0100	2.039	1.984
1.1431	28.951	28.171	1.0738	15.087	14.680	1.0080	1.631	1.588
1.1410	28.544	27.772	1.0718	14.679	14.284	1.0060	1.124	1.191
1.1389	28.136	27.376	1.0697	14.271	13.887	1.0040	0.816	0.795
1.1369	27.728	26.979	1.0677	13.863	13.490	1.0020	0.409	0.397
1.1349	27.321	26.583						

346. TABLE SHOWING THE STRENGTH OF SOLUTIONS OF AMMONIA BY SPECIFIC GRAVITY AT 14° C.—(ABRIDGED FROM CARIUS' TABLE.)

Per Cent Ammonia (NH₃).	Specific Gravity.	Per Cent Ammonia (NH₃).	Specific Gravity.	Per Cent Ammonia (NH₃).	Specific Gravity.
1.	0.9059	13.	0.9484	25.	0.9106
1.4	0.9941	13.4	0.9470	25.4	0.9094
2.	0.9915	14.	0.9449	26.	0.9078
2.4	0.9899	14.4	0.9434	26.4	0.9068
3.	0.9873	15.	0.9414	27.	0.9052
3.4	0.9855	15.4	0.9400	27.4	0.9041
4.	0.9831	16.	0.9380	28.	0.9026
4.4	0.9815	16.4	0.9366	28.4	0.9016
5.	0.9790	17.	0.9347	29.	0.9001
5.4	0.9773	17.4	0.9333	29.4	0.8991
6.	0.9749	18.	0.9314	30.	0.8976
6.4	0.9733	18.4	0.9302	30.4	0.8967
7.	0.9709	19.	0.9288	31.	0.8953
7.4	0.9693	19.4	0.9271	31.4	0.8943
8.	0.9670	20.	0.9251	32.	0.8929
8.4	0.9654	20.4	0.9239	32.4	0.8920
9.	0.9631	21.	0.9221	33.	0.8907
9.4	0.9616	21.4	0.9209	33.4	0.8898
10.	0.9593	22.	0.9191	34.	0.8885
10.4	0.9578	22.4	0.9180	34.4	0.8877
11.	0.9556	23.	0.9162	35.	0.8864
11.4	0.9542	23.4	0.9150	35.4	0.8856
12.	0.9520	24.	0.9133	36.	0.8844
12.4	0.9505	24.4	0.9122		

347. TABLE SHOWING THE PERCENTAGE OF ACETATE OF LEAD IN SOLUTIONS OF THE SALT, OF DIFFERENT DENSITIES, AT 15° C.—(GERLACH.)

Specific Gravity.	Per Cent of the Salt.	Specific Gravity.	Per Cent of the Salt.	Specific Gravity.	Per Cent of the Salt.
1 0127	2	1.1384	20	1.2768	36
1.0255	4	1.1544	22	1.2966	38
1.0386	6	1.1704	24	1.3163	40
1.0520	8	1.1869	26	1 3376	42
1.0654	10	1.2040	28	1.3588	44
1.0796	12	1.2211	30	1.3810	46
1.0739	14	1.2395	32	1.4041	48
1.1084	16	1.2578	34	1.4271	50
1.1234	18				

348. TABLE SHOWING THE QUANTITY OF SODIUM OXIDE IN SOLUTIONS OF VARIOUS DENSITIES.

(Fresenius Anl. z. quant. Analyse. V. Aufl. f. 730.)

ACCORDING TO DALTON.		ACCORDING TO TÜNNERMANN AT 15° C.					
Sp. Gr.	Per Cent Na_2O.	Sp. Gr.	Per Cent Na_2O.	Sp. Gr.	Per Cent Na_2O.	Sp. Gr.	Per Cent Na_2O.
2.00	77.8	1.4285	30.220	1.2982	20.550	1.1528	10.275
1.85	63.6	1.4193	29.616	1.2912	19.945	1.1428	9.670
1.72	53.8	1.4101	29.011	1.2843	19.341	1.1380	9.066
1.63	46.6	1.4011	28.407	1.2775	18.730	1.1233	8.462
1.56	41.2	1.3923	27.802	1.2708	18.132	1.1137	7.857
1.50	36.8	1.3836	27.200	1.2642	17.528	1.1042	7.253
1.47	34.0	1.3751	26.594	1.2578	16.923	1.0948	6.648
1.44	31.0	1.3668	25.989	1.2515	16.319	1.0855	6.044
1.40	29.0	1.3586	25.385	1.2453	15.714	1.0764	5.440
1.36	26.0	1.3505	24.780	1.2392	15.110	1.0675	4.835
1.32	23.0	1.3426	24.176	1.2280	14.506	1.0587	4.231
1.29	19.0	1.3349	23.572	1.2178	13.901	1.0500	3.626
1.23	16.0	1.3273	22.967	1.2058	13.297	1.0414	3.022
1.18	13.0	1.3198	22.363	1.1948	12.692	1.0330	2.418
1.12	9.0	1.3143	21.894	1.1841	12.088	1.0246	1.813
1.06	4.7	1.3125	21.758	1.1734	11.484	1.0163	1.209
		1.3053	21.154	1.1630	10.879	1.0081	0.604

349. TABLE SHOWING THE QUANTITY OF POTASSIC OXIDE IN SOLUTIONS OF VARIOUS DENSITIES.

(Fresenius Anl. z. quant. Analyse. V. Aufl. f. 730.)

ACCORDING TO DALTON.		ACCORDING TO TÜNNERMANN AT 15° C.			
Sp. Gr.	K_2O Per Cent.	Sp. Gr.	K_2O. Per Cent.	Sp. Gr.	K_2O. Per Cent.
1.68	51.2	1.3300	28.290	1.1437	14.145
1.60	47.7	1.3131	27.158	1.1308	13.013
1.52	42.9	1.2966	26.027	1.1182	11.882
1.47	39.9	1.2803	24.895	1.1059	10.750
1.44	36.8	1.2648	23.764	1.0938	9.619
1.42	34.4	1.2493	22.632	1.0819	8.487
1.39	32.4	1.2342	21.500	1.0703	7.355
1.36	29.4	1.2268	20.935	1.0589	6.224
1.32	26.3	1.2122	19.803	1.0478	5.002
1.28	23.4	1.1979	18.671	1.0369	3.961
1.23	19.5	1.1839	17.540	1.0260	2.829
1.19	16.2	1.1702	16.408	1.0153	1.697
1.15	13.0	1.1568	15.277	1.0050	0.5658
1.11	9.5				
1.06	4.7				

350. TABLE SHOWING THE SPECIFIC GRAVITY OF CANE-SUGAR SOLUTIONS OF VARIOUS CONCENTRATIONS AND THE CORRESPONDING DEGREES BRIX.[1]

Observed density at 20° C. referred to water at 4° C.

Per Cent Sucrose = Degree Brix.	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
0	0.998234	0.998622	0.999010	0.999398	0.999786	1.000174	1.000563	1.000952	1.001342	1.001731
1	1.002120	1.002509	1.002897	1.003286	1.003675	1.004064	1.004453	1.004844	1.005234	1.005624
2	1.006015	1.006405	1.006796	1.007188	1.007580	1.007972	1.008363	1.008755	1.009148	1.009541
3	1.009934	1.010327	1.010721	1.011115	1.011510	1.011904	1.012298	1.012694	1.013089	1.013485
4	1.013881	1.014277	1.014673	1.015070	1.015467	1.015864	1.016261	1.016659	1.017058	1.017456
5	1.017854	1.018253	1.018652	1.019052	1.019451	1.019851	1.020251	1.020651	1.021053	1.021454
6	1.021855	1.022257	1.022659	1.023061	1.023463	1.023867	1.024270	1.024673	1.025077	1.025481
7	1.025885	1.026289	1.026694	1.027099	1.027504	1.027910	1.028316	1.028722	1.029128	1.029535
8	1.029942	1.030349	1.030757	1.031165	1.031573	1.031982	1.032391	1.032800	1.033209	1.033619
9	1.034029	1.034439	1.034850	1.035260	1.035671	1.036082	1.036494	1.036906	1.037318	1.037730
10	1.038143	1.038556	1.038970	1.039383	1.039797	1.040212	1.040626	1.041041	1.041456	1.041872
11	1.042288	1.042704	1.043121	1.043537	1.043954	1.044370	1.044788	1.045206	1.045625	1.046043
12	1.046462	1.046881	1.047300	1.047720	1.048140	1.048559	1.048980	1.049401	1.049822	1.050243
13	1.050665	1.051087	1.051510	1.051933	1.052356	1.052778	1.053202	1.053626	1.054050	1.054475
14	1.054900	1.055325	1.055751	1.056176	1.056602	1.057029	1.057455	1.057882	1.058310	1.058737
15	1.059165	1.059593	1.060022	1.060451	1.060880	1.061308	1.061738	1.062168	1.062598	1.063029
16	1.063460	1.063892	1.064324	1.064756	1.065188	1.065621	1.066054	1.066487	1.066921	1.067355
17	1.067789	1.068223	1.068658	1.069093	1.069529	1.069964	1.070400	1.070836	1.071273	1.071710
18	1.072147	1.072585	1.073023	1.073461	1.073900	1.074338	1.074777	1.075217	1.075657	1.076097
19	1.076537	1.076978	1.077419	1.077860	1.078302	1.078744	1.079187	1.079629	1.080072	1.080515

[1] Kaiserliche Normaleichungskommission. Zeitschrift des Vereins Deutscher Zuckerindustrie 1900, 1123.

SPECIFIC GRAVITY OF SUGAR SOLUTIONS—(Continued).

Observed density at 20° C. referred to water at 4° C.

Per Cent Sucrose = Degree Brix.	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
20	1.080959	1.081403	1.081848	1.082292	1.082737	1.083182	1.083628	1.084074	1.084520	1.084967
21	1.085414	1.085861	1.086309	1.086757	1.087205	1.087652	1.088101	1.088550	1.089000	1.089450
22	1.089900	1.090351	1.090802	1.091253	1.091704	1.092155	1.092607	1.093060	1.093513	1.093966
23	1.094420	1.094874	1.095328	1.095782	1.096236	1.096691	1.097147	1.097603	1.098058	1.098514
24	1.098971	1.099428	1.099886	1.100344	1.100802	1.101259	1.101718	1.102177	1.102637	1.103097
25	1.103557	1.104017	1.104478	1.104938	1.105400	1.105862	1.106324	1.106786	1.107248	1.107711
26	1.108175	1.108639	1.109103	1.109568	1.110033	1.110497	1.110963	1.111429	1.111895	1.112361
27	1.112828	1.113295	1.113763	1.114229	1.114697	1.115166	1.115635	1.116104	1.116572	1.117042
28	1.117512	1.117982	1.118453	1.118923	1.119395	1.119867	1.120339	1.120812	1.121284	1.121757
29	1.122231	1.122705	1.123179	1.123653	1.124128	1.124603	1.125079	1.125555	1.126030	1.126507
30	1.126984	1.127461	1.127939	1.128417	1.128896	1.129374	1.129853	1.130332	1.130812	1.131292
31	1.131773	1.132254	1.132735	1.133216	1.133698	1.134180	1.134663	1.135146	1.135628	1.136112
32	1.136596	1.137080	1.137565	1.138049	1.138534	1.139020	1.139506	1.139993	1.140479	1.140966
33	1.141453	1.141941	1.142429	1.142916	1.143405	1.143894	1.144384	1.144874	1.145363	1.145854
34	1.146345	1.146836	1.147328	1.147820	1.148313	1.148805	1.149298	1.149792	1.150286	1.150780
35	1.151275	1.151770	1.152265	1.152760	1.153256	1.153752	1.154249	1.154746	1.155242	1.155740
36	1.156238	1.156736	1.157235	1.157733	1.158233	1.158733	1.159233	1.159733	1.160233	1.160734
37	1.161236	1.161738	1.162240	1.162742	1.163245	1.163748	1.164252	1.164756	1.165259	1.165764
38	1.166269	1.166775	1.167281	1.167786	1.168293	1.168800	1.169307	1.169815	1.170322	1.170831
39	1.171340	1.171849	1.172359	1.172869	1.173379	1.173889	1.174400	1.174911	1.175423	1.175935

SPECIFIC GRAVITY OF SUGAR SOLUTIONS—(Continued).

Observed density at 20° C. referred to water at 4° C.

Per Cent Sucrose = Degree Brix	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
40	1.176447	1.176960	1.177473	1.177987	1.178501	1.179014	1.179527	1.180044	1.180560	1.181076
41	1.181592	1.182108	1.182625	1.183142	1.183660	1.184178	1.184696	1.185215	1.185734	1.186253
42	1.186773	1.187293	1.187814	1.188335	1.188856	1.189379	1.189901	1.190423	1.190946	1.191469
43	1.191993	1.192517	1.193041	1.193565	1.194090	1.194616	1.195141	1.195667	1.196193	1.196720
44	1.197247	1.197775	1.198303	1.198832	1.199360	1.199890	1.200420	1.200950	1.201480	1.202010
45	1.202540	1.203071	1.203603	1.204136	1.204668	1.205200	1.205733	1.206266	1.206801	1.207335
46	1.207870	1.208405	1.208940	1.209477	1.210013	1.210549	1.211086	1.211623	1.212162	1.212700
47	1.213238	1.213777	1.214317	1.214856	1.215395	1.215936	1.216476	1.217017	1.217559	1.218101
48	1.218643	1.219185	1.219729	1.220272	1.220815	1.221360	1.221904	1.222449	1.222995	1.223540
49	1.224086	1.224632	1.225180	1.225727	1.226274	1.226823	1.227371	1.227919	1.228469	1.229018
50	1.229567	1.230117	1.230668	1.231219	1.231770	1.232322	1.232874	1.233426	1.233979	1.234532
51	1.235085	1.235639	1.236194	1.236748	1.237303	1.237859	1.238414	1.238970	1.239527	1.240084
52	1.240641	1.241198	1.241757	1.242315	1.242873	1.243433	1.243992	1.244552	1.245113	1.245673
53	1.246234	1.246795	1.247358	1.247920	1.248482	1.249046	1.249609	1.250172	1.250737	1.251301
54	1.251866	1.252431	1.252997	1.253563	1.254129	1.254697	1.255264	1.255831	1.256400	1.256967
55	1.257535	1.258104	1.258674	1.259244	1.259815	1.260385	1.260955	1.261527	1.262099	1.262671
56	1.263243	1.263816	1.264390	1.264963	1.265537	1.266112	1.266686	1.267261	1.267837	1.268413
57	1.268989	1.269565	1.270143	1.270720	1.271299	1.271877	1.272455	1.273035	1.273614	1.274194
58	1.274774	1.275354	1.275936	1.276517	1.277098	1.277680	1.278262	1.278844	1.279428	1.280011
59	1.280595	1.281179	1.281764	1.282349	1.282935	1.283521	1.284107	1.284694	1.285281	1.285869

SPECIFIC GRAVITY OF SUGAR SOLUTIONS—(*Continued*).

Observed density at 20° C. referred to water at 4° C.

Per Cent Sucrose = Degree Brix.	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
60	1.286456	1.287044	1.287633	1.288222	1.288811	1.289401	1.289991	1.290581	1.291172	1.291763
61	1.292354	1.292946	1.293539	1.294131	1.294725	1.295318	1.295911	1.296506	1.297100	1.297696
62	1.298291	1.298886	1.299483	1.300079	1.300677	1.301274	1.301871	1.302470	1.303068	1.303668
63	1.304267	1.304867	1.305467	1.306068	1.306669	1.307271	1.307872	1.308475	1.309077	1.309680
64	1.310282	1.310885	1.311489	1.312093	1.312699	1.313304	1.313909	1.314515	1.315121	1.315728
65	1.316334	1.316941	1.317549	1.318157	1.318766	1.319374	1.319983	1.320593	1.321203	1.321814
66	1.322425	1.323036	1.323648	1.324259	1.324872	1.325484	1.326097	1.326711	1.327325	1.327940
67	1.328554	1.329170	1.329785	1.330401	1.331017	1.331633	1.332250	1.332868	1.333485	1.334103
68	1.334722	1.335342	1.335961	1.336581	1.337200	1.337821	1.338441	1.339063	1.339684	1.340306
69	1.340928	1.341551	1.342174	1.342798	1.343421	1.344046	1.344671	1.345296	1.345922	1.346547
70	1.347174	1.347801	1.348427	1.349055	1.349682	1.350311	1.350939	1.351568	1.352197	1.352827
71	1.353456	1.354087	1.354717	1.355349	1.355980	1.356612	1.357245	1.357877	1.358511	1.359144
72	1.359778	1.360413	1.361047	1.361682	1.362317	1.362953	1.363590	1.364226	1.364864	1.365501
73	1.366139	1.366777	1.367415	1.368054	1.368693	1.369333	1.369973	1.370613	1.371245	1.371894
74	1.372536	1.373178	1.373820	1.374463	1.375105	1.375749	1.376392	1.377036	1.377680	1.378326
75	1.378971	1.379617	1.380262	1.380909	1.381555	1.382203	1.382851	1.383499	1.384148	1.384796
76	1.385446	1.386096	1.386745	1.387396	1.388045	1.388696	1.389347	1.389999	1.390651	1.391303
77	1.391956	1.392610	1.393263	1.393917	1.394571	1.395226	1.395881	1.396536	1.397192	1.397848
78	1.398505	1.399162	1.399819	1.400477	1.401134	1.401793	1.402452	1.403111	1.403771	1.404430
79	1.405091	1.405752	1.406412	1.407074	1.407735	1.408398	1.409061	1.409723	1.410387	1.411051

SPECIFIC GRAVITY OF SUGAR SOLUTIONS—(Continued).

Observed density at 20° C. referred to water at 4° C.

Per Cent Sucrose = Degree Brix	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
80	1.411715	1.412380	1.413044	1.413709	1.414374	1.415040	1.415706	1.416373	1.417039	1.417707
81	1.418374	1.419043	1.419711	1.420380	1.421049	1.521719	1.422390	1.423059	1.423730	1.424400
82	1.425072	1.425744	1.426416	1.427089	1.427761	1.428435	1.429109	1.429782	1.430457	1.431131
83	1.431807	1.432483	1.433158	1.433835	1.434511	1.435188	1.435866	1.436543	1.437222	1.437900
84	1.438579	1.439259	1.439938	1.440619	1.441299	1.441980	1.442661	1.443342	1.444024	1.444705
85	1.445388	1.446071	1.446754	1.447438	1.448121	1.448806	1.449491	1.450175	1.450860	1.451545
86	1.452232	1.452919	1.453605	1.454292	1.454980	1.455668	1.456357	1.457045	1.457735	1.458424
87	1.459114	1.459805	1.460495	1.461186	1.461877	1.462568	1.463260	1.463953	1.464645	1.465338
88	1.466032	1.466726	1.467420	1.468115	1.468810	1.469504	1.470200	1.470896	1.471592	1.472289
89	1.472986	1.473684	1.474381	1.475080	1.475779	1.476477	1.477176	1.477876	1.478575	1.479275
90	1.479976	1.480677	1.481378	1.482080	1.482782	1.483484	1.484187	1.484890	1.485593	1.486297
91	1.487002	1.487707	1.488411	1.489117	1.489823	1.490528	1.491234	1.491941	1.492647	1.493355
92	1.494063	1.494771	1.495479	1.496188	1.496897	1.497606	1.498316	1.499026	1.499736	1.500447
93	1.501158	1.501870	1.502582	1.503293	1.504006	1.504719	1.505432	1.506146	1.506859	1.507574
94	1.508289	1.509004	1.509720	1.510435	1.511151	1.511868	1.512585	1.513302	1.514019	1.514737
95	1.515465	1.516174	1.516893	1.517612	1.518332	1.519051	1.519771	1.520492	1.521212	1.521934
96	1.522656	1.523378	1.524100	1.524823	1.525546	1.526269	1.526993	1.527717	1.528441	1.529166
97	1.529891	1.530616	1.531342	1.532068	1.532794	1.533521	1.534248	1.534976	1.535704	1.536432
98	1.537161	1.537889	1.538618	1.539347	1.540076	1.540806	1.541536	1.542267	1.542998	1.543730
99	1.544462	1.545194	1.545926	1.546659	1.547392	1.548127	1.548861	1.549595	1.550329	1.551064
100	1.551800									

351. TABLE SHOWING A COMPARISON OF THE DEGREES BRIX AND BAUMÉ, AND OF THE SPECIFIC GRAVITY OF SUGAR SOLUTIONS AT 17½° C.—(Stammer.)[1]

Degree Brix (Per Cent Sugar).	Degree Baumé (corrected).	Specific Gravity.	Degree Brix (Per Cent Sugar).	Degree Baumé (corrected).	Specific Gravity.	Degree Brix (Per Cent Sugar).	Degree Baumé (corrected).	Specific Gravity.
0.0	0.0	1.00000	3.0	1.7	1.01173	6.0	3.4	1.02373
.1	0 1	1.00038	.1	1.8	1.01213	.1	3 5	1.02413
.2	0.1	1.00077	.2	1.8	1.01252	.2	3.5	1.02454
.3	0 2	1.00116	.3	1.9	1.01292	.3	3 6	1.02494
.4	0.2	1.00155	.4	1.9	1.01332	.4	3.6	1.02535
.5	0.3	1 00193	.5	2.0	1.01371	.5	3 7	1.02575
.6	0.3	1.00232	.6	2 0	1.01411	.6	3.7	1.02616
.7	0.4	1.00271	.7	2.1	1.01451	.7	3.8	1.02657
.8	0.45	1.00310	8	2.2	1.01491	.8	3 9	1.02694
.9	0.5	1.00349	.9	2.2	1.01531	.9	3 9	1.02738
1.0	0.6	1.00388	4.0	2.3	1.01570	7.0	4.0	1.02779
.1	0.6	1.00427	.1	2.3	1.01610	.1	4.0	1.02819
.2	0.7	1.00466	.2	2.4	1.01650	.2	4.1	1.02860
.3	0.7	1.00505	.3	2.4	1.01690	.3	4.1	1.02901
.4	0.8	1.00544	.4	2.5	1.01730	.4	4 2	1.02942
.5	0.85	1.00583	.5	2.55	1.01770	.5	4.25	1.02983
.6	0 9	1.00622	.6	2.6	1.01810	.6	4.3	1.03024
.7	1.0	1.00662	.7	2.7	1.01850	.7	4.4	1.03064
.8	1.0	1.00701	.8	2.7	1.01890	.8	4.4	1.03105
.9	1.1	1.00740	.9	2.8	1.01930	.9	4.5	1.03146
2.0	1.1	1.00779	5.0	2.8	1.01970	8.0	4.5	1.03187
.1	1 2	1.00818	.1	2.9	1.02010	.1	4.6	1.03228
.2	1.2	1.00858	.2	2 95	1.02051	.2	4.6	1.03270
.3	1.3	1.00897	.3	3.0	1.02091	.3	4.7	1.03311
.4	1.4	1.00936	.4	3.1	1.02131	.4	4.8	1.03352
.5	1.4	1.00976	.5	3.1	1.02171	.5	4.8	1.03393
.6	1.5	1.01015	.6	3.2	1.02211	.6	4.9	1.03434
.7	1.5	1.01055	.7	3.2	1.02252	.7	4.9	1.03475
.8	1.6	1.01094	.8	3.3	1.02292	.8	5.0	1.03517
.9	1.6	1.01134	.9	3.35	1.02333	.9	5.0	1.03558

CORRECTION FOR TEMPERATURE, BRIX SPINDLE.—(Gerlach.)

Temp. ° C.	Temp. ° F.	Approximate Degree Brix and Correction.			
		0	5	10	15
13	55.4	.14	.18	.19	.21
14	57.2	.12	.15	.16	.17
15	59.	.09	.11	.12	.14
16	60.8	.06	.07	.08	.09
17	62.6	.02	.02	.02	.03
18	64.4	.02	.03	.03	.03
19	66.2	.06	.08	.08	.09
20	68.	.11	.14	.15	.17
21	69.8	.16	.20	.22	.24
22	71.6	.21	.26	.29	.31
23	73.4	.27	.32	.35	.37
24	75.2	.32	.38	.41	.43
25	77.	.37	.44	.47	.49

Subtract. Note.—For temperatures above 17½° C. add the correction to the reading at the observed temperature; below 17½° subtract.

Add. Obtain Baumé corrections from the corresponding degree Brix.

[1] The degrees Baumé of this table are the corrected or "new" degrees according to Gerlach.

TABLE SHOWING A COMPARISON OF THE DEGREES BRIX AND BAUMÉ, ETC., OF SUGAR SOLUTIONS.—*Continued.*

Degree Brix (Per Cent Sugar).	Degree Baumé (corrected).	Specific Gravity.	Degree Brix (Per Cent Sugar).	Degree Baumé (corrected).	Specific Gravity.	Degree Brix (Per Cent Sugar).	Degree Baumé (corrected).	Specific Gravity.
9.0	5.1	1.03599	12.0	6.8	1.04852	15.0	8.5	1.06133
.1	5.2	1.03640	.1	6.8	1.04894	.1	8.5	1.06176
.2	5.2	1.03682	.2	6.9	1.04937	.2	8.55	1.06219
.3	5.3	1.03723	.3	7.0	1.04979	.3	8.6	1.06262
.4	5.3	1.03765	.4	7.0	1.05021	.4	8.7	1.06306
.5	5.4	1.03806	.5	7.1	1.05064	.5	8.8	1.06349
.6	5.4	1.03848	.6	7.1	1.05106	.6	8.8	1.06392
.7	5.5	1.03889	.7	7.2	1.05149	.7	8.9	1.06436
.8	5.55	1.03931	.8	7.2	1.05191	.8	8.9	1.06479
.9	5.6	1.03972	.9	7.3	1.05233	.9	9.0	1.06522
10.0	5.7	1.04014	13.0	7.4	1.05276	16.0	9.0	1.06566
.1	5.7	1.04055	.1	7.4	1.05318	.1	9.1	1.06609
.2	5.8	1.04097	.2	7.5	1.05361	.2	9.2	1.06653
.3	5.8	1.04139	.3	7.5	1.05404	.3	9.2	1.06696
.4	5.9	1.04180	.4	7.6	1.05446	.4	9.3	1.06740
.5	5.9	1.04222	.5	7.6	1.05489	.5	9.3	1.06783
.6	6.0	1.04264	.6	7.7	1.05532	.6	9.4	1.06827
.7	6.1	1.04306	.7	7.75	1.05574	.7	9.4	1.06871
.8	6.1	1.04348	.8	7.8	1.05617	.8	9.5	1.06914
.9	6.2	1.04390	.9	7.9	1.05660	.9	9.5	1.06958
11.0	6.2	1.04431	14.0	7.9	1.05703	17.0	9.6	1.07002
.1	6.3	1.04473	.1	8.0	1.05746	.1	9.7	1.07046
.2	6.3	1.04515	.2	8.0	1.05789	.2	9.7	1.07090
.3	6.4	1.04557	.3	8.1	1.05831	.3	9.8	1.07133
.4	6.5	1.04599	.4	8.1	1.05874	.4	9.8	1.07177
.5	6.5	1.04641	.5	8.2	1.05917	.5	9.9	1.07221
.6	6.6	1.04683	.6	8.3	1.05960	.6	9.9	1.07265
.7	6.6	1.04726	.7	8.3	1.06003	.7	10.0	1.07309
.8	6.7	1.04768	.8	8.4	1.06047	.8	10.0	1.07353
.9	6.7	1.04810	.9	8.4	1.06090	.9	10.1	1.07397

CORRECTION FOR TEMPERATURE, BRIX SPINDLE.—(GERLACH.)

Temp. °C.	Temp. °F.	APPROXIMATE DEGREE BRIX AND CORRECTION.				
		15	20	25	30	
13	55.4	.21	.22	.24	.26	Subtract. NOTE.—For temperatures above 17½° C. add the correction to the reading at the observed temperature; below 17½° C. subtract.
14	57.2	.17	.18	.19	.21	
15	59.	.14	.14	.15	.16	
16	60.8	.09	.10	.10	.11	
17	62.6	.03	.03	.04	.04	
18	64.4	.03	.03	.03	.03	Add.
19	66.2	.09	.09	.10	.10	
20	68.	.17	.17	.18	.18	Obtain Baumé corrections from corresponding degree Brix.
21	69.8	.24	.24	.25	.25	
22	71.6	.31	.31	.32	.32	
23	73.4	.37	.38	.39	.39	
24	75.2	.43	.44	.46	.46	
25	77.	.49	.51	.53	.54	

TABLE SHOWING A COMPARISON OF THE DEGREES BRIX
AND BAUMÉ, ETC.—*Continued.*

Degree Brix (Per Cent Sugar).	Degree Baumé (corrected).	Specific Gravity.	Degree Brix (Per Cent Sugar).	Degree Baumé (corrected).	Specific Gravity.	Degree Brix (Per Cent Sugar).	Degree Baumé (corrected).	Specific Gravity.
18.0	10.1	1.07441	23.0	13.0	1.09686	28.0	15.7	1.12013
.1	10.2	1 07485	.1	13.0	1.09732	.1	15.8	1.12060
.2	10.3	1.07530	.2	13.1	1.09777	.2	15.8	1.12107
.3	10.3	1.07574	.3	13.1	1.09823	.3	15.9	1.12155
.4	10.4	1 07618	.4	13.2	1.09869	.4	16.0	1.12202
.5	10.4	1.07662	.5	13.2	1.09915	.5	16.0	1.12250
.6	10.5	1.07706	.6	13.3	1.09961	.6	16.1	1.12297
.7	10.5	1.07751	.7	13.3	1.10007	.7	16.1	1.12345
.8	10.6	1.07795	.8	13.4	1.10053	.8	16.2	1.12393
.9	10 6	1.07839	.9	13.5	1.10099	.9	16.2	1.12440
19.0	10.7	1.07884	24.0	13.5	1.10145	29.0	16 3	1.12488
.1	10.8	1.07928	.1	13.6	1.10191	.1	16 3	1.12536
.2	10.8	1.07973	.2	13 6	1.10237	.2	16.4	1.12583
.3	10.9	1 08017	.3	13.7	1.10283	.3	16.5	1.12631
.4	10.9	1.08062	.4	13.7	1.10329	.4	16.5	1.12679
.5	11.0	1.08106	.5	13.8	1.10375	.5	16.6	1.12727
.6	11.1	1.08151	.6	13.8	1.10421	.6	16.6	1.12775
.7	11.1	1.08196	.7	13.9	1.10468	.7	16.7	1.12823
.8	11.2	1.08240	.8	14.0	1 10514	.8	16.7	1.12871
.9	11.2	1.08285	.9	14.0	1.10560	.9	16.8	1.12919
20.0	11.3	1.08329	25.0	14.1	1.10607	30.0	16.8	1.12967
.1	11.3	1.08374	.1	14.1	1.10653	.1	16.9	1.13015
.2	11.4	1.08419	.2	14.2	1.10700	.2	16.95	1.13063
.3	11.5	1.08464	.3	14.2	1.10746	.3	17.0	1.13111
.4	11.5	1.08509	.4	14.3	1.10793	.4	17.1	1.13159
.5	11.6	1.08553	.5	14.3	1.10839	.5	17.1	1.13207
.6	11.6	1.08599	.6	14.4	1.10886	.6	17.2	1.13255
.7	11.7	1.08643	.7	14.5	1.10932	.7	17.2	1.13304
.8	11.7	1.08688	.8	14.5	1.10979	.8	17.3	1.13352
.9	11.8	1.08733	.9	14.6	1.11026	.9	17.3	1.13400
21.0	11.8	1.08778	26.0	14.6	1.11072	31.0	17.4	1.13449
.1	11.9	1.08824	.1	14.7	1.11119	.1	17.4	1.13497
.2	11.95	1.08869	.2	14.7	1.11166	.2	17.5	1.13545
.3	12.0	1.08914	.3	14.8	1.11213	.3	17.6	1.13594
.4	12.0	1.08950	.4	14.85	1.11259	.4	17.6	1.13642
.5	12.1	1.09004	.5	14.9	1.11306	.5	17.7	1.13691
.6	12.1	1 09049	.6	15.0	1 11353	.6	17.7	1.13740
.7	12.2	1.09095	.7	15.0	1.11400	.7	17.8	1.13788
.8	12.3	1 09140	.8	15.1	1.11447	.8	17.8	1.13837
.9	12.3	1.09185	.9	15.1	1.11494	.9	17.9	1.13885
22.0	12.4	1.09231	27.0	15.2	1.11541	32.0	17.95	1.13934
.1	12.5	1.09276	.1	15.2	1.11588	.1	18.0	1.13983
.2	12.5	1.09321	.2	15.3	1.11635	.2	18.0	1.14032
.3	12.6	1.09367	.3	15 3	1.11682	.3	18.1	1.14081
.4	12.6	1.09412	.4	15.4	1.11729	.4	18.2	1.14129
.5	12.7	1.09458	.5	15.5	1.11776	.5	18.2	1.14178
.6	12.7	1.09508	.6	15.5	1.11824	.6	18.3	1.14227
.7	12.8	1.09549	.7	15.6	1.11871	.7	18.3	1.14276
.8	12.85	1.09595	.8	15.6	1.11918	.8	18.4	1.14325
.9	12.9	1.09640	.9	15.7	1.11965	.9	18.4	1.14374

TABLE SHOWING A COMPARISON OF THE DEGREES BRIX AND BAUMÉ, ETC.—*Continued.*

Degree Brix (Per Cent Sugar).	Degree Baumé (corrected).	Specific Gravity.	Degree Brix (Per Cent Sugar).	Degree Baumé (corrected).	Specific Gravity.	Degree Brix (Per Cent Sugar).	Degree Baumé (corrected).	Specific Gravity.
33.0	18.5	1.14423	38.0	21.2	1.16920	43.0	23.95	1.19505
.1	18.55	1.14472	.1	21.3	1.16971	.1	24.0	1.19558
.2	18.6	1.14521	.2	21.35	1.17022	.2	24.1	1.19611
.3	18.7	1.14570	.3	21 4	1.17072	.3	24.1	1.19653
.4	18.7	1.14620	.4	21.5	1.17123	.4	24.2	1.19716
.5	18.8	1.14669	.5	21.5	1.17174	.5	24.2	1.19769
.6	18.8	1.14718	.6	21 6	1.17225	.6	24.3	1.19822
.7	18.9	1.14767	.7	21.6	1.17276	.7	24.3	1.19875
.8	18.9	1.14817	.8	21.7	1.17327	.8	24.4	1.19927
.9	19.0	1.14866	.9	21.7	1.17379	.9	24.4	1:19980
34.0	19.05	1.14915	39.0	21.8	1.17430	44.0	24.5	1.20033
.1	19.1	1.14965	.1	21.8	1.17481	.1	24.55	1.20086
.2	19.2	1.15014	.2	21.9	1.17582	.2	24.6	1.20139
.3	19.2	1.15064	.3	21.9	1.17583	.3	24.65	1.20192
.4	19.3	1.15113	.4	22.0	1.17635	.4	24.7	1.20245
.5	19.3	1.15163	.5	22.05	1.17686	.5	24.8	1.20299
.6	19.4	1.15213	.6	22.1	1.17737	.6	24.8	1.20352
.7	19.4	1.15262	.7	22.2	1.17789	.7	24.9	1.20405
.8	19.5	1.15312	.8	22.2	1.17840	.8	24.9	1.20458
.9	19.5	1.1'362	.9	22.3	1.17892	.9	25.0	1.20513
35.0	19.6	1.15411	40.0	22.3	1.17948	45.0	25.0	1.20565
.1	19.65	1.15461	.1	22.4	1.17995	.1	25.1	1.20618
.2	19.7	1.15511	.2	22.4	1.18046	.2	25.1	1.20672
.3	19 8	1.15561	.3	22.5	1.18098	.3	25.2	1.20725
.4	19.8	1.15611	.4	22.5	1.18150	.4	25.2	1.20779
.5	19 9	1.15661	.5	22.6	1.18201	.5	25.3	1.20832
.6	19.9	1.15710	.6	22.6	1.18253	.6	25.4	1.20886
.7	20.0	1.15760	.7	22.7	1.18305	.7	25.4	1.20939
.8	20.0	1.15810	.8	22.8	1.18357	.8	25.5	1.20993
.9	20.1	1.15861	.9	22.8	1.18408	.9	25.5	1.21046
36.0	20.1	1.15911	41.0	22.9	1.18460	46.0	25 6	1.21100
.1	20.2	1.15961	.1	22.9	1.18512	.1	25.6	1.21154
.2	20.25	1.16011	.2	23.0	1.18564	.2	25.7	1.21208
.3	20.3	1.16051	.3	23.0	1.18616	.3	25.7	1.21261
.4	20.4	1.16111	.4	23.1	1.18668	.4	25.8	1 21315
.5	20.4	1.16162	.5	23.1	1.18720	.5	25.8	1.21369
.6	20.5	1.16212	.6	23.2	1.18772	.6	25.9	1.21423
.7	20.5	1.16262	.7	23.25	1.18824	.7	25.95	1.21477
.8	20.6	1.16313	.8	23.3	1.18877	.8	26.0	1.21531
.9	20.6	1.16363	.9	23.4	1.18929	.9	26.1	1.21585
37.0	20.7	1.16413	42.0	23.4	1.18981	47.0	26.1	1.21639
.1	20.7	1.16464	.1	23.5	1.19033	.1	26.2	1.21693
.2	20 8	1.16514	.2	23.5	1.19086	.2	26.2	1.21747
.3	20.9	1.16565	.3	23.6	1.19138	.3	26.3	1.21802
.4	20.9	1.16616	.4	23.6	1.19190	.4	26.3	1.21856
.5	21.0	1.16666	.5	23.7	1.19243	.5	26.4	1.21910
.6	21.0	1.16717	.6	23.7	1.19295	.6	26.4	1.21964
.7	21.1	1.16768	.7	23.8	1.19348	.7	26.5	1.22019
.8	21.1	1.16818	.8	23.8	1.19400	.8	26.5	1.22073
.9	21.2	1.16869	.9	23.9	1.19453	.9	26.6	1.22127

TABLE SHOWING A COMPARISON OF THE DEGREES BRIX AND BAUMÉ, ETC.—*Continued.*

Degree Brix (Per Cent Sugar).	Degree Baumé (corrected).	Specific Gravity.	Degree Brix (Per Cent Sugar).	Degree Baumé (corrected).	Specific Gravity.	Degree Brix (Per Cent Sugar).	Degree Baumé (corrected).	Specific Gravity.
48.0	26.6	1.22182	53.0	29.3	1.24951	58.0	31.9	1.27816
.1	26.7	1.22236	.1	29.4	1.25008	.1	32.0	1.27874
.2	26.75	1.22291	.2	29.4	1.25064	.2	32.0	1.27932
.3	26.8	1.22315	.3	29.5	1.25120	.3	32.1	1.27991
.4	26.9	1.22400	.4	29.5	1.25177	.4	32.15	1.28049
.5	26.9	1.22455	.5	29.6	1.25233	.5	32.2	1.28107
.6	27.0	1.22509	.6	29.6	1.25290	.6	32.3	1.28166
.7	27.0	1.22564	.7	29.7	1.25347	.7	32.3	1.28224
.8	27.1	1.22619	.8	29.7	1.25408	.8	32.4	1.28283
.9	27.1	1.22672	.9	29.8	1.25460	.9	32.4	1.28342
49.0	27.2	1.22728	54.0	29.8	1.25517	59.0	32.5	1.28400
.1	27.2	1.22788	.1	29.9	1.25573	.1	32.5	1.28459
.2	27.3	1.22838	.2	29.9	1.25630	.2	32.6	1.28518
.3	27.3	1.22898	.3	30.0	1.25687	.3	32.6	1.28576
.4	27.4	1.22948	.4	30.05	1.25747	.4	32.7	1.28635
.5	27.4	1.23003	.5	30.1	1.25801	.5	32.7	1.28694
.6	27.5	1.23058	.6	30.2	1.25857	.6	32.8	1.28753
.7	27.6	1.23113	.7	30.2	1.25914	.7	32.8	1.28812
.8	27.6	1.23168	.8	30.3	1.25971	.8	32.9	1.28871
.9	27.7	1.23223	.9	30.3	1.26028	.9	32.9	1.28930
50.0	27.7	1.23278	55.0	30.4	1.26086	60.0	33.0	1.28969
.1	27.8	1.23334	.1	30.4	1.26143	.1	33.0	1.29048
.2	27.8	1.23389	.2	30.5	1.26200	.2	33.1	1.29107
.3	27.9	1.23444	.3	30.5	1.26257	.3	33.1	1.29166
.4	27.9	1.23499	.4	30.6	1.26314	.4	33.2	1.29225
.5	28.0	1.23555	.5	30.6	1.26372	.5	33.2	1.29284
.6	28.0	1.23610	.6	30.7	1.26429	.6	33.3	1.29343
.7	28.1	1.23666	.7	30.7	1.26486	.7	33.35	1.29403
.8	28.1	1.23721	.8	30.8	1.26514	.8	33.4	1.29462
.9	28.2	1.23777	.9	30.8	1.26601	.9	33.45	1.29521
51.0	28.2	1.23832	56.0	30.9	1.26658	61.0	33.5	1.29581
.1	28.3	1.23884	.1	30.9	1.26716	.1	33.6	1.29640
.2	28.35	1.23943	.2	31.0	1.26773	.2	33.6	1.29700
.3	28.4	1.23999	.3	31.05	1.26831	.3	33.7	1.29759
.4	28.5	1.24055	.4	31.1	1.26889	.4	33.7	1.29819
.5	28.5	1.24111	.5	31.2	1.26946	.5	33.8	1.29878
.6	28.6	1.24166	.6	31.2	1.27004	.6	33.8	1.29938
.7	28.6	1.24222	.7	31.3	1.27062	.7	33.9	1.29998
.8	28.7	1.24278	.8	31.3	1.27120	.8	33.9	1.30057
.9	28.7	1.24384	.9	31.4	1.27177	.9	34.0	1.30117
52.0	28.8	1.24390	57.0	31.4	1.27235	62.0	34.0	1.30177
.1	28.8	1.24446	.1	31.5	1.27293	.1	34.1	1.30237
.2	28.9	1.24502	.2	31.5	1.27351	.2	34.1	1.30297
.3	28.9	1.24558	.3	31.6	1.27409	.3	34.2	1.30356
.4	29.0	1.24614	.4	31.6	1.27464	.4	34.2	1.30416
.5	29.0	1.24670	.5	31.7	1.27525	.5	34.3	1.30476
.6	29.1	1.24726	.6	31.7	1.27583	.6	34.3	1.30536
.7	29.15	1.24782	.7	31.8	1.27641	.7	34.4	1.30596
.8	29.2	1.24839	.8	31.8	1.27699	.8	34.4	1.30657
.9	29.2	1.24895	.9	31.9	1.27758	.9	34.5	1.30717

TABLE SHOWING A COMPARISON OF THE DEGREES BRIX AND BAUMÉ, ETC.—*Continued.*

Degree brix (Per Cent Sugar).	Degree Baumé (corrected).	Specific Gravity.	Degree Brix (Per Cent Sugar).	Degree Baumé (corrected).	Specific Gravity.	Degree Brix (Per Cent Sugar).	Degree Baumé (corrected).	Specific Gravity.
63.0	34.5	1.30777	68.0	37.1	1.33836	73.0	39.6	1.36995
.1	34.6	1.30837	.1	37.1	1.33899	.1	39.7	1.37059
.2	34.6	1.30897	.2	37.2	1.33961	.2	39.7	1.37124
.3	34.7	1.30958	.3	37.3	1.34023	.3	39.8	1.37188
.4	34.7	1.31018	.4	37.3	1.34085	.4	39.8	1.37252
.5	34.8	1.31078	.5	37.4	1.34148	.5	39.9	1.37317
.6	34.85	1.31139	.6	37.4	1.34210	.6	39.9	1.37381
.7	34.9	1.31199	.7	37.5	1.34273	.7	40.0	1.37446
.8	34.95	1.31260	.8	37.5	1.34335	.8	40.0	1.37510
.9	35.0	1.31320	.9	37.6	1.34398	.9	40.1	1.37575
64.0	35.1	1.31381	69.0	37.6	1.34460	74.0	40.1	1.37639
.1	35.1	1.31442	.1	37.7	1.34523	.1	40.2	1.37704
.2	35.2	1.31502	.2	37.7	1.34585	.2	40.2	1.37768
.3	35.2	1.31563	.3	37.8	1.34648	.3	40.3	1.37833
.4	35.3	1.31624	.4	37.8	1.34711	.4	40.3	1.37898
.5	35.3	1.31684	.5	37.9	1.34774	.5	40.4	1.37962
.6	35.4	1.31745	.6	37.9	1.34836	.6	40.4	1.38027
.7	35.4	1.31806	.7	38.0	1.34899	.7	40.5	1.38092
.8	35.5	1.31867	.8	38.0	1.34962	.8	40.5	1.38157
.9	35.5	1.31928	.9	38.1	1.35025	.9	40.6	1.38222
65.0	35.6	1.31989	70.0	38.1	1.35088	75.0	40.6	1.38287
.1	35.6	1.32050	.1	38.2	1.35151	.1	40.7	1.38352
.2	35.7	1.32111	.2	38.2	1.35214	.2	40.7	1.38417
.3	35.7	1.32172	.3	38.3	1.35277	.3	40.8	1.38482
.4	35.8	1.32233	.4	38.3	1.35340	.4	40.8	1.38547
.5	35.8	1.32294	.5	38.4	1.35403	.5	40.9	1.38612
.6	35.9	1.32355	.6	38.4	1.35466	.6	40.9	1.38677
.7	35.9	1.32417	.7	38.5	1.35530	.7	41.0	1.38743
.8	36.0	1.32478	.8	38.5	1.35593	.8	41.0	1.38808
.9	36.0	1.32539	.9	38.6	1.35656	.9	41.1	1.38873
66.0	36.1	1.32601	71.0	38.6	1.35720	76.0	41.1	1.38939
.1	36.1	1.32662	.1	38.7	1.35783	.1	41.2	1.39004
.2	36.2	1.32724	.2	38.7	1.35847	.2	41.2	1.39070
.3	36.2	1.32785	.3	38.8	1.35910	.3	41.3	1.39135
.4	36.3	1.32847	.4	38.8	1.35974	.4	41.3	1.39201
.5	36.3	1.32908	.5	38.9	1.36037	.5	41.4	1.39266
.6	36.4	1.32970	.6	38.9	1.36101	.6	41.4	1.39332
.7	36.4	1.33031	.7	39.0	1.36164	.7	41.5	1.39397
.8	36.5	1.33093	.8	39.0	1.36228	.8	41.5	1.39463
.9	36.5	1.33155	.9	39.1	1.36292	.9	41.6	1.39529
67.0	36.6	1.33217	72.0	39.1	1.36355	77.0	41.6	1.39595
.1	36.6	1.33278	.1	39.2	1.36419	.1	41.7	1.39660
.2	36.7	1.33340	.2	39.2	1.36483	.2	41.7	1.39726
.3	36.75	1.33402	.3	39.3	1.36547	.3	41.8	1.39792
.4	36.8	1.33464	.4	39.3	1.36611	.4	41.8	1.39858
.5	36.85	1.33526	.5	39.4	1.36675	.5	41.9	1.39924
.6	36.9	1.33588	.6	39.4	1.36739	.6	41.9	1.39990
.7	36.95	1.33650	.7	39.5	1.36803	.7	42.0	1.40056
.8	37.0	1.33712	.8	39.5	1.36867	.8	42.0	1.40122
.9	37.0	1.33774	.9	39.6	1.36931	.9	42.1	1.40188

TABLE SHOWING A COMPARISON OF THE DEGREES BRIX AND BAUMÉ, ETC.—*Continued*.

Degree Brix (Per Cent Sugar).	Degree Baumé (corrected).	Specific Gravity.	Degree Brix (Per Cent Sugar).	Degree Baumé (corrected).	Specific Gravity.	Degree Brix (Per Cent Sugar).	Degree Baumé (corrected).	Specific Gravity.
78.0	42.1	1.40254	83.0	44.6	1.43614	88.0	47.0	1.47074
.1	42.2	1.40321	.1	44.6	1.43682	.1	47.0	1.47145
.2	42.2	1.40387	.2	44.7	1.43750	.2	47.1	1.47215
.3	42.3	1.40453	.3	44.7	1.43819	.3	47.1	1.47285
.4	42.3	1.40520	.4	44.8	1.43887	.4	47.2	1.47356
.5	42.4	1.40586	.5	44 8	1.43955	.5	47.2	1.47426
.6	42.4	1.40652	.6	44.9	1.44024	.6	47.3	1.47496
.7	42.5	1.40719	.7	44.9	1.44092	.7	47.3	1.47567
.8	42.5	1.40785	.8	45.0	1.44161	.8	47.4	1.47637
.9	42.6	1.40852	.9	45.0	1.44229	.9	47.4	1.47708
79.0	42.6	1.40918	84.0	45.1	1.44298	89.0	47.45	1.47778
.1	42.7	1.40985	.1	45.1	1.44367	.1	47.5	1.47849
.2	42.7	1.41052	.2	45.15	1.44435	.2	47.55	1.47920
.3	42.8	1.41118	.3	45.2	1.44504	.3	47.6	1.47991
.4	42.8	1.41185	.4	45.25	1.44573	.4	47.6	1.48061
.5	42.9	1.41252	.5	45.3	1.44641	.5	47.7	1.48132
.6	42.9	1.41318	.6	45.35	1.44710	.6	47.7	1.48203
.7	43.0	1.41385	.7	45.4	1.44779	.7	47.8	1.48274
.8	43.0	1.41452	.8	45.4	1.44848	.8	47.8	1.48345
.9	43.1	1.41519	.9	45.5	1.44917	.9	47.9	1.48416
80.0	43.1	1.41586	85.0	45.5	1.44986	90.0	47.9	1.48486
.1	43.2	1.41653	.1	45.6	1.45055	.1	48.0	1.48558
.2	43.2	1.41720	.2	45.6	1.45124	.2	48.0	1.48629
.3	43.2	1.41787	.3	45.7	1.45193	.3	48.1	1.48700
.4	43.3	1.41854	.4	45.7	1.45262	.4	48.1	1.48771
.5	43.3	1.41921	.5	45.8	1.45331	.5	48.2	1.48842
.6	43.4	1.41989	.6	45.8	1.45401	.6	48.2	1.48913
.7	43.45	1.42056	.7	45.9	1.45470	.7	48.3	1.48985
.8	43.5	1.42123	.8	45.9	1.45539	.8	48.3	1.49056
.9	43.55	1.42190	.9	46.0	1.45609	.9	48.35	1.49127
81.0	43.6	1.42258	86.0	46.0	1.45678	91.0	48.4	1.49199
.1	43.65	1.42325	.1	46.1	1.45748	.1	48.4	1.49270
.2	43.7	1.42393	.2	46.1	1.45817	.2	48.5	1.49342
.3	43.7	1.42460	.3	46.2	1.45887	.3	48 5	1.49413
.4	43.8	1.42528	.4	46.2	1.45956	.4	48.6	1.49485
.5	43.8	1.42595	.5	46.3	1.46026	.5	48.6	1.49556
.6	43.9	1.42663	.6	46.3	1.46095	.6	48.7	1.49628
.7	43.9	1.42731	.7	46.35	1.46165	.7	48.7	1.49700
.8	44.0	1.42798	.8	46.4	1.46235	8	48.8	1.49771
.9	44.0	1.42866	.9	46.45	1.46304	.9	48.8	1.49843
82.0	44.1	1.42934	87.0	46.5	1.46374	92.0	48.9	1.49915
.1	44.1	1.43002	.1	46.55	1.46444	.1	48.9	1.49987
.2	44.2	1.43070	.2	46.6	1.46514	.2	49.0	1.50058
.3	44.2	1.43137	.3	46.65	1.46584	.3	49.0	1.50130
.4	44.3	1.43205	.4	46.7	1.46654	.4	49.05	1.50202
.5	44.3	1.43273	.5	46.7	1.46724	.5	49.1	1.50274
.6	44.4	1.43341	.6	46.8	1.46794	.6	49.15	1.50346
.7	44.4	1.43409	.7	46.8	1.46864	.7	49.2	1.50419
.8	44.5	1.43478	.8	46.9	1.46934	.8	49.2	1.50491
.9	44.5	1.43546	.9	46.9	1.47004	.9	49.3	1.50563

TABLE SHOWING A COMPARISON OF THE DEGREES BRIX AND BAUME, ETC.—*Continued*.

Degree Brix (Per Cent Sugar).	Degree Baumé (corrected).	Specific Gravity.	Degree Brix (Per Cent Sugar).	Degree Baumé (corrected).	Specific Gravity.
93.0	49.3	1.50635	94.0	49.8	1.51359
.1	49.4	1.50707	.1	49.85	1.51431
.2	49.4	1.50779	.2	49.9	1.51504
.3	49.5	1.50852	.3	49.9	1.51577
.4	49.5	1.50924	.4	50.0	1.51649
.5	49 6	1.50996	.5	50.0	1.51722
.6	49.6	1.51069	.6	50.1	1.51795
.7	49.7	1.51141	.7	50.1	1.51868
.8	49.7	1.51214	.8	50.2	1.51941
.9	49.8	1.51286	.9	50.2	1.52014
			95.0	50.3	1.52087

352. TABLE FOR THE CORRECTION OF READINGS ON THE BRIX SCALE FOR VARIATIONS IN TEMPERATURE FROM THE STANDARD, 17½° C. (63½° F.).—(Gerlach.)

Temp. ° C.	Temp. ° F.	APPROXIMATE DEGREE BRIX AND CORRECTION.											
		0	5	10	15	20	25	30	35	40	50	60	70	75
0	32	.27	.30	.41	.52	.62	.72	.82	.92	.98	1.11	1.22	1.25	1.29
5	41	.23	.30	.37	.44	.52	.59	.65	.72	.75	.80	.88	.91	.94
10	50	.20	.26	.29	.33	.36	.39	.42	.45	.48	.50	.54	.58	.61
11	51.8	.18	.23	.26	.28	.31	.34	.36	.39	.41	.43	.47	.50	.53
12	53.6	.16	.20	.22	.24	.26	.29	.31	.33	.34	.36	.40	.42	.46
13	55.4	.14	.18	.19	.21	.22	.24	.26	.27	.28	.29	.33	.35	.39
14	57.2	.12	.15	.16	.17	.18	.19	.21	.22	.22	.23	.26	.28	.32
15	59	.09	.11	.12	.14	.14	.15	.16	.17	.17	.17	.19	.21	.25
16	60.8	.06	.07	.08	.09	.10	.10	.11	.12	.12	.12	.14	.16	.18
17	62.6	.02	.02	.03	.03	.03	.04	.04	.04	.04	.04	.05	.05	.06

Add the correction to readings above 17½° C. (63½ F.) and subtract the correction from those below this temperature

18	64.4	.02	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.02
19	66.2	.06	.08	.08	.09	.09	.10	.10	.10	.10	.10	.10	.08	.06
20	68	.11	.14	.15	.17	.17	.18	.18	.18	.19	.19	.18	.15	.11
21	69.8	.16	.20	.22	.24	.24	.25	.25	.25	.26	.26	.25	.22	.18
22	71.6	.21	.26	.29	.31	.31	.32	.32	.34	.33	.34	.32	.29	.25
23	73.4	.27	.32	.35	.37	.38	.39	.39	.39	.40	.42	.39	.36	.33
24	75.2	.32	.38	.41	.43	.44	.46	.46	.47	.47	.50	.46	.43	.40
25	77	.37	.44	.47	.49	.51	.53	.54	.55	.55	.58	.54	.51	.48
26	78.8	.43	.50	.54	.56	.58	.60	.61	.62	.62	.66	.62	.58	.55
27	80.6	.49	.57	.61	.63	.65	.68	.68	.69	.70	.74	.70	.65	.62
28	82.4	.56	.64	.68	.70	.72	.76	.76	.78	.78	.82	.78	.72	.70
29	84.2	.63	.71	.75	.78	.79	.84	.84	.86	.86	.90	.86	.80	.78
30	86	.70	.78	.82	.87	.87	.92	.92	.94	.94	.98	.94	.88	.86
35	95	1.10	1.17	1.22	1.24	1.30	1.32	1.33	1.35	1.36	1.39	1.34	1.27	1.25
40	104	1.50	1.61	1.67	1.71	1.73	1.79	1.79	1.80	1.82	1.83	1.78	1.69	1.65
50	122		2.65	2.71	2.74	2.78	2.80	2.80	2.80	2.80	2.79	2.70	2.56	2.51
60	140		3.87	3.88	3.88	3.88	3.88	3.88	3.88	3.90	3.82	3.70	3.43	3.41
70	158			5.18	5.20	5.14	5.13	5.10	5.08	5.06	4.90	4.72	4.47	4.35
80	176			6.62	6.59	6.54	6.46	6.38	6.30	6.26	6.06	5.82	5.50	5.33

353. TEMPERATURE CORRECTIONS TO READINGS OF SACCHAROMETERS (STANDARD AT 20° C.) [1]

[This table is calculated using the data on thermal expansion of sugar solutions by Plato,[2] assuming the instrument to be of Jena 16III glass. The table should be used with caution and only for approximate results when the temperature differs much from the standard temperature or from the temperature of the surrounding air.]

Temp. °C.	Observed Per Cent of Sugar.													
	0	5	10	15	20	25	30	35	40	45	50	55	60	70
	Subtract from Observed Per Cent.													
0	0.30	0.49	0.65	0.77	0.89	0.99	1.08	1.16	1.24	1.31	1.37	1.41	1.44	1.49
5	.36	.47	.56	.65	.73	.80	.86	.91	.97	1.01	1.05	1.08	1.10	1.14
10	.32	.38	.43	.48	.52	.57	.60	.64	.67	.70	.72	.74	.75	.77
11	.31	.35	.40	.44	.48	.51	.55	.58	.60	.63	.65	.66	.68	.70
12	.29	.32	.36	.40	.43	.46	.50	.52	.54	.56	.58	.59	.60	.62
13	.26	.29	.32	.35	.38	.41	.44	.46	.48	.49	.51	.52	.53	.55
14	.24	.26	.29	.31	.34	.36	.38	.40	.41	.42	.44	.45	.46	.47
15	.20	.22	.24	.26	.28	.30	.32	.33	.34	.36	.36	.37	.38	.39
16	.17	.18	.20	.22	.23	.25	.26	.27	.28	.28	.29	.30	.31	.32
17	.13	.14	.15	.16	.18	.19	.20	.20	.21	.21	.22	.23	.23	.24
18	.09	.10	.10	.11	.13	.13	.13	.14	.14	.14	.15	.15	.15	.16
19	.05	.05	.05	.06	.06	.06	.07	.07	.07	.07	.08	.08	.08	.08

[1] From Circular No. 19, 1914, U. S. Bureau of Standards, p. 25.
[2] Wiss. Abb. der Kaiserlichen Normal-Eichungs-Kommission, 2, p. 140, 1900.

TEMPERATURE CORRECTIONS TO READINGS OF SACCHAROMETERS.—Continued.

Temp. °C.	Observed Per Cent of Sugar.													
	0	5	10	15	20	25	30	35	40	45	50	55	60	70
	Add to Observed Per Cent.													
21	0.04	.05	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.08	.0.08	0.08	0.08	0.09
22	.10	.10	.11	.12	.12	.13	.14	.14	.14	.15	.16	.16	.16	.16
23	.16	.16	.17	.17	.19	.20	.21	.21	.22	.23	.24	.24	.24	.24
24	.21	.22	.23	.24	.26	.27	.28	.29	.30	.31	.32	.32	.32	.32
25	.27	.28	.30	.31	.32	.34	.35	.36	.38	.38	.39	.39	.40	.39
26	.33	.34	.36	.37	.40	.40	.42	.44	.46	.47	.47	.48	.48	.48
27	.40	.41	.42	.44	.46	.48	.50	.52	.54	.54	.55	.56	.56	.56
28	.46	.47	.49	.51	.54	.56	.58	.60	.61	.62	.63	.64	.64	.64
29	.54	.55	.56	.59	.61	.63	.66	.68	.70	.70	.71	.72	.72	.72
30	.61	.62	.63	.66	.68	.70	.73	.76	.78	.78	.79	.80	.80	.81
35	.99	1.01	1.02	1.06	1.10	1.13	1.16	1.18	1.20	1.21	1.22	1.22	1.23	1.22
40	1.42	1.45	1.47	1.51	1.54	1.57	1.62	1.62	1.64	1.65	1.65	1.65	1.66	1.65
45	1.91	1.94	1.96	2.00	2.03	2.05	2.07	2.09	2.10	2.10	2.10	2.10	2.10	2.08
50	2.46	2.48	2.50	2.53	2.56	2.57	2.58	2.59	2.59	2.58	2.58	2.57	2.56	2.52
55	3.05	3.07	3.09	3.12	3.12	3.12	3.12	3.11	3.10	3.08	3.07	3.05	3.03	2.97
60	3.69	3.72	3.73	3.73	3.72	3.70	3.67	3.65	3.62	3.60	3.57	3.54	3.50	3.43

354. GEERLIGS' TABLE FOR DRY SUBSTANCE IN SUGAR-HOUSE PRODUCTS BY ABBE REFRACTOMETER, AT 28° C.

[Intern. Sugar J., **10**, p. 69.]

Index Refraction.	Per Cent Dry. Substance.	Decimals.	Decimals.
1.3335	1	0.0001 = 0.05	0.0010 = 0.75
1.3349	2	0.0002 = 0.1	0.0011 = 0.8
1.3364	3	0.0003 = 0.2	0.0012 = 0.8
1.3379	4	0.0004 = 0.25	0.0013 = 0.85
1.3394	5	0.0005 = 0.3	0.0014 = 0.9
1.3409	6	0.0006 = 0.4	0.0015 = 1.0
1.3424	7	0.0007 = 0.5	
1.3439	8	0.0008 = 0.6	
1.3454	9	0.0009 = 0.7	
1.3469	10		
1.3484	11	0.0001 = 0.05	
1.3500	12	0.0002 = 0.1	
1.3516	13	0 0003 = 0.2	
1.3530	14	0.0004 = 0.25	
1.3546	15	0.0005 = 0.3	
1.3562	16	0.0006 = 0.4	
1.3578	17	0.0007 = 0.45	
1.3594	18	0.0008 = 0.5	
1.3611	19	0.0009 = 0.6	
1.3627	20	0.0010 = 0.65	
1.3644	21	0.0011 = 0.7	
1.3661	22	0.0012 = 0.75	
1.3678	23	0.0013 = 0.8	
1.3695	24	0.0014 = 0.85	
1.3712	25	0.0015 = 0.9	
1.3729	26	0.0016 = 0.95	
1.3746	27	0.0001 = 0.05	0.0012 = 0.6
1.3764	28	0.0002 = 0.1	0.0013 = 0.65
1.3782	29	0.0003 = 0.15	0.0014 = 0.7
1.3800	30	0.0004 = 0.2	0.0015 = 0.75
1.3818	31	0.0005 = 0.25	0.0016 = 0.8
1.3836	32	0.0006 = 0.3	0.0017 = 0.85
1.3854	33	0.0007 = 0.35	0.0018 = 0.9
1.3872	34	0.0008 = 0.4	0.0019 = 0.95
1.3890	35	0.0009 = 0.45	0.0020 = 1.0
1.3909	36	0.0010 = 0.5	0.0021 = 1.0
1.3928	37	0.0011 = 0.55	
1.3947	38		
1.3966	39		
1.3984	40		
1.4003	41		
1.4023	42	0.0001 = 0.05	0.0012 = 0.6
1.4043	43	0.0002 = 0.1	0.0013 = 0.65
1.4063	44	0.0003 = 0.15	0.0014 = 0.7
1.4083	45	0.0004 = 0.2	0.0015 = 0.75

GEERLIGS' TABLE FOR DRY SUBSTANCE IN SUGAR-HOUSE PRODUCTS.—*Continued.*

Index Refraction.	Per Cent Dry. Substance.	Decimals.	Decimals.
1.4104	46	0.0005 = 0.25	0.0016 = 0.8
1.4124	47	0.0006 = 0.3	0.0017 = 0.85
1.4145	48	0.0007 = 0.35	0.0018 = 0.9
1.4166	49	0.0008 = 0.4	0.0019 = 0.95
1.4186	50	0.0009 = 0.45	0.0020 = 1.0
1.4207	51	0.0010 = 0.5	0.0021 = 1.0
1.4228	52	0.0011 = 0.55	
1.4249	53		
1.4270	54		
1.4292	55	0.0001 = 0.05	0.0013 = 0.55
1.4314	56	0.0002 = 0.1	0.0014 = 0.6
1.4337	57	0.0003 = 0.1	0.0015 = 0.65
1.4359	58	0.0004 = 0.15	0.0016 = 0.7
1.4382	59	0.0005 = 0.2	0.0017 = 0.75
1.4405	60	0.0006 = 0.25	0.0018 = 0.8
1.4428	61	0.0007 = 0.3	0.0019 = 0.85
1.4451	62	0.0008 = 0.35	0.0020 = 0.9
1.4474	63	0.0009 = 0.4	0.0021 = 0.9
1.4497	64	0.0010 = 0.45	0.0022 = 0.95
1.4520	65	0.0011 = 0.5	0.0023 = 1.0
1.4543	66	0.0012 = 0.5	0.0024 = 1.0
1.4567	67		
1.4591	68		
1.4615	69		
1.4639	70		
1.4663	71		
1.4687	72		
1.4711	73	0.0001 = 0.0	0.0015 = 0.55
1.4736	74	0.0002 = 0.05	0.0016 = 0.6
1.4761	75	0.0003 = 0.1	0.0017 = 0.65
1.4786	76	0.0004 = 0.15	0.0018 = 0.65
1.4811	77	0.0005 = 0.2	0.0019 = 0.7
1.4836	78	0.0006 = 0.2	0.0020 = 0.75
1.4862	79	0.0007 = 0.25	0.0021 = 0.8
1.4888	80	0.0008 = 0.3	0.0022 = 0.8
1.4914	81	0.0009 = 0.35	0.0023 = 0.85
1.4940	82	0.0010 = 0.35	0.0024 = 0.9
1.4966	83	0.0011 = 0.4	0.0025 = 0.9
1.4992	84	0.0012 = 0.45	0.0026 = 0.95
1.5019	85	0.0013 = 0.5	0.0027 = 1.0
1.5046	86	0.0014 = 0.5	0.0028 = 1.0
1.5073	87		
1.5100	88		
1.5127	89		
1.5155	90		

TABLE OF CORRECTIONS FOR TEMPERATURE.

Dry Substance by Refractometer (Geerligs').

Temp. of the prisms in °C.	Dry Substance.												
	0	5	10	15	20	25	30	40	50	60	70	80	90
	Subtract—												
20	0.53	0.54	0.55	0.56	0.57	0.58	0.60	0.62	0.64	0.62	0.61	0.60	0.58
21	0.46	0.47	0.48	0.49	0.50	0.51	0.52	0.54	0.56	0.54	0.53	0.52	0.50
22	0.40	0.41	0.42	0.42	0.43	0.44	0.45	0.47	0.48	0.47	0.46	0.45	0.44
23	0.33	0.33	0.34	0.35	0.36	0.37	0.38	0.39	0.40	0.39	0.38	0.38	0.38
24	0.26	0.26	0.27	0.28	0.28	0.29	0.30	0.31	0.32	0.31	0.31	0.30	0.30
25	0.20	0.20	0.21	0.21	0.22	0.22	0.23	0.23	0.24	0.23	0.23	0.23	0.22
26	0.12	0.12	0.13	0.14	0.14	0.14	0.15	0.15	0.16	0.16	0.16	0.15	0.14
27	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.07
	Add—												
29	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.07
30	0.12	0.12	0.13	0.14	0.14	0.14	0.15	0.15	0.16	0.16	0.16	0.15	0.14
31	0.20	0.20	0.21	0.21	0.22	0.22	0.23	0.23	0.24	0.23	0.23	0.23	0.22
32	0.26	0.26	0.27	0.28	0.28	0.29	0.30	0.31	0.32	0.31	0.31	0.30	0.30
33	0.33	0.33	0.34	0.35	0.36	0.37	0.38	0.39	0.40	0.39	0.38	0.38	0.38
34	0.40	0.41	0.42	0.42	0.43	0.44	0.45	0.47	0.48	0.47	0.46	0.45	0.44
35	0.46	0.47	0.48	0.49	0.50	0.51	0.52	0.54	0.56	0.54	0.53	0.52	0.50

355. TABLE SHOWING THE WEIGHT PER CUBIC FOOT AND U. S. GALLON (231 Cu.in.) AND SOLIDS (Brix) OF SUGAR SOLUTIONS AT 17½° C.

(Based upon Stammer's Table, p. 482.)

Degree. Brix.	Weight of		Solids (Brix) per		Degree Brix.	Weight of		Solids (Brix) per	
	1 cu.ft.	1 gal.	1 cu.ft.	1 gal.		1 cu.ft.	1 gal.	1 cu.ft.	1 gal.
	Lbs.	Lbs.	Lbs.	Lbs.		Lbs.	Lbs.	Lbs.	Lbs.
1.0	62.59	8.36	0.63	0.08	20.0	67.55	9.03	13.51	1.81
.5	62.72	8.38	0.94	.08	.25	67.62	9.04	13.69	1.83
2.0	62.84	8.39	1.26	.17	.50	67.69	9.04	13.88	1.85
.5	62.96	8.40	1.57	.21	.75	67.76	9.05	14.06	1.88
3.0	63.08	8.42	1.89	.25	21.0	67.83	9.06	14.24	1.90
.5	63.20	8.44	2.21	.30	.25	67.90	9.07	14.42	1.93
4.0	63.32	8.46	2.53	.34	.50	67.97	9.08	14.61	1.95
.5	63.44	8.48	2.86	.38	.75	68.04	9.09	14.79	1.98
5.0	63.57	8.50	3.18	.43	22.0	68.11	9.10	14.98	2.00
.5	63.70	8.52	3.50	.47	.25	68.18	9.11	15.17	2.03
6.0	63.83	8.53	3.83	.51	.50	68.25	9.12	15.36	2.05
.5	63.95	8.55	4.16	.56	.75	68.32	9.13	15.54	2.08
7.0	64.08	8.57	4.49	.60	23.0	68.39	9.14	15.73	2.10
.5	64.21	8.59	4.82	.64	.25	68.46	9.15	15.92	2.13
8.0	64.34	8.60	5.15	.69	.50	68.54	9.16	16.11	2.15
.5	64.47	8.61	5.48	.73	.75	68.61	9.17	16.29	2.18
9.0	64.60	8.63	5.81	.78	24.0	68.68	9.18	16.48	2.20
.5	64.72	8.65	6.15	.82	.25	68.75	9.19	16.66	2.23
10.0	64.84	8.67	6.48	.87	.50	68.82	9.20	16.86	2.25
.25	64.91	8.68	6.65	.89	.75	68.89	9.21	17.05	2.28
.50	64.97	8.69	6.82	.91	25.0	68.96	9.22	17.24	2.31
.75	65.04	8.70	6.99	.94	.25	69.04	9.23	17.43	2.33
11.0	65.11	8.71	7.16	.96	.50	69.11	9.24	17.62	2.36
.25	65.18	8.71	7.33	.98	.75	69.19	9.25	17.81	2.38
.50	65.24	8.72	7.50	1.00	26.0	69.26	9.26	18.01	2.41
.75	65.31	8.73	7.67	1.03	.25	69.34	9.26	18.20	2.44
12.0	65.37	8.74	7.84	1.05	.50	69.41	9.27	18.39	2.47
.25	65.44	8.75	8.01	1.08	.75	69.48	9.28	18.58	2.49
.50	65.51	8.76	8.19	1.10	27.0	69.55	9.29	18.78	2.51
.75	65.58	8.77	8.36	1.12	.25	69.62	9.30	18.98	2.53
13.0	65.64	8.78	8.53	1.14	.50	69.69	9.31	19.17	2.56
.25	65.71	8.78	8.70	1.17	.75	69.76	9.32	19.36	2.59
.50	65.77	8.79	8.88	1.19	28.0	69.84	9.33	19.56	2.61
.75	65.84	8.80	9.05	1.21	.25	69.91	9.34	19.75	2.63
14.0	65.91	8.81	9.23	1.23	.50	69.99	9.35	19.95	2.66
.25	65.98	8.81	9.40	1.26	.75	70.06	9.36	20.14	2.68
.50	66.04	8.82	9.58	1.28	29.0	70.14	9.37	20.34	2.71
.75	66.11	8.83	9.75	1.31	.25	70.21	9.38	20.54	2.73
15.0	66.18	8.84	9.93	1.33	.50	70.29	9.39	20.74	2.76
.25	66.25	8.85	10.10	1.36	.75	70.36	9.40	20.93	2.79
.50	66.31	8.86	10.28	1.38	30.0	70.43	9.41	21.13	2.82
.75	66.38	8.87	10.45	1.40	.25	70.52	9.42	21.33	2.85
16.0	66.44	8.88	10.63	1.42	.50	70.59	9.43	21.53	2.88
.25	66.51	8.89	10.80	1.44	.75	70.67	9.44	21.73	2.90
.50	66.58	8.90	10.97	1.47	31.0	70.74	9.45	21.93	2.93
.75	66.65	8.91	11.14	1.50	.25	70.82	9.46	22.13	2.96
17.0	66.72	8.92	11.34	1.52	.50	70.89	9.47	22.33	2.99
.25	66.79	8.93	11.52	1.55	.75	70.97	9.48	22.53	3.02
.50	66.85	8.93	11.70	1.57	32.0	71.04	9.49	22.73	3.04
.75	66.92	8.94	11.88	1.59	.25	71.12	9.50	22.93	3.07
18.0	66.99	8.95	12.06	1.61	.50	71.19	9.51	23.14	3.09
.25	67.06	8.96	12.24	1.64	.75	71.27	9.52	23.34	3.12
.50	67.13	8.97	12.42	1.66	33.0	71.35	9.53	23.55	3.14
.75	67.20	8.98	12.60	1.69	.25	71.43	9.54	23.75	3.17
19.0	67.27	8.99	12.78	1.71	.50	71.50	9.55	23.95	3.20
.25	67.34	9.00	12.96	1.74	.75	71.57	9.56	24.15	3.23
.50	67.41	9.01	13.14	1.76	34.0	71.65	9.58	24.36	3.26
.75	67.48	9.02	13.32	1.79	.25	71.72	9.59	24.56	3.29

WEIGHT PER CUBIC FOOT—*Continued.*

De-gree Brix.	Weight of 1 cu.ft.	Weight of 1 gal.	Solids (Brix) per 1 cu.ft.	Solids (Brix) per 1 gal.	De-gree Brix.	Weight of 1 cu.ft.	Weight of 1 gal.	Solids (Brix) per 1 cu.ft.	Solids (Brix) per 1 gal.
	Lbs.	Lbs.	Lbs.	Lbs.		Lbs.	Lbs.	Lbs.	Lbs.
34.50	71.80	9.60	24.77	3.32	50.0	76.87	10.27	38.44	5.14
.75	71.88	9.61	24.98	3.35	.25	76.96	10.28	38.68	5.17
35.0	71.96	9.62	25.19	3.37	.50	77.04	10.29	38.91	5.20
.25	72.04	9.63	25.39	3.40	.75	77.12	10.30	39.15	5.23
.50	72.11	9.64	25.60	3.43	51.0	77.21	10.31	39.38	5.26
.75	72.19	9.65	25.81	3.46	.25	77.29	10.32	39.62	5.29
36.0	72.27	9.66	26.02	3.48	.50	77.38	10.34	39.85	5.32
.25	72.35	9.67	26.23	3.51	.75	77.47	10.35	40.09	5.35
.50	72.43	9.68	26.44	3.54	52.0	77.56	10.36	40.33	5.39
.75	72.51	9.69	26.65	3.57	.25	77.64	10.37	40.57	5.42
37.0	72.59	9.70	26.86	3.59	.50	77.73	10.38	40.81	5.45
.25	72.67	9.71	27.07	3.62	.75	77.82	10.39	41.05	5.48
.50	72.74	9.72	27.28	3.65	53.0	77.91	10.41	41.29	5.52
.75	72.82	9.73	27.49	3.68	.25	77.99	10.42	41.53	5.55
38.0	72.90	9.74	27.71	3.70	.50	78.08	10.43	41.77	5.58
.25	72.98	9.75	27.92	3.73	.75	78.17	10.44	42.01	5.61
.50	73.06	9.76	28.13	3.76	54.0	78.26	10.46	42.26	5.65
.75	73.14	9.77	28.34	3.79	.25	78.35	10.47	42.51	5.68
39.0	73.22	9.78	28.56	3.81	.50	78.44	10.48	42.75	5.71
.25	73.30	9.79	28.77	3.84	.75	78.53	10.49	43.00	5.74
.50	73.38	9.80	29.99	3.87	55.0	78.62	10.51	43.24	5.78
.75	73.46	9.81	29.20	3.90	.25	78.71	10.52	43.49	5.81
40.0	73.54	9.83	29.42	3.93	.50	78.79	10.53	43.73	5.84
.25	73.62	9.84	29.63	3.96	.75	78.88	10.54	43.98	5.87
.50	73.70	9.85	29.85	3.99	56.0	78.97	10.55	44.22	5.91
.75	73.78	9.86	30.07	4.02	.25	79.06	10.56	44.47	5.94
41.0	73.86	9.87	30.29	4.04	.50	79.15	10.57	44.71	5.97
.25	73.94	9.89	30.50	4.07	.75	79.24	10.58	44.96	6.00
.50	74.02	9.89	30.72	4.10	57.0	79.33	10.60	45.21	6.04
.75	74.10	9.90	30.94	4.13	.25	79.42	10.61	45.47	6.08
42.0	74.18	9.91	31.16	4.16	.50	79.51	10.62	45.72	6.11
.25	74.26	9.92	31.38	4.19	.75	79.59	10.63	45.98	6.15
.50	74.34	9.93	31.60	4.22	58.0	79.70	10.65	46.23	6.18
.75	74.42	9.94	31.82	4.25	.25	79.78	10.66	46.48	6.21
43.0	74.51	9.96	32.04	4.28	.50	79.87	10.67	46.74	6.25
.25	74.59	9.97	32.26	4.31	.75	79.96	10.68	46.99	6.28
.50	74.67	9.98	32.49	4.34	59.0	80.05	10.70	47.25	6.32
.75	74.75	9.99	32.71	4.37	.25	80.14	10.71	47.50	6.35
44.0	74.84	10.00	32.93	4.40	.50	80.24	10.72	47.76	6.38
.25	74.92	10.01	33.15	4.43	.75	80.34	10.73	48.26	6.41
.50	75.00	10.02	33.38	4.46	60.0	80.43	10.75	48.52	6.45
.75	75.08	10.03	33.60	4.49	.25	80.53	10.76	48.52	6.48
45.0	75.17	10.05	33.83	4.52	.50	80.62	10.77	48.78	6.52
.25	75.25	10.06	34.05	4.55	.75	80.71	10.78	49.04	6.55
.50	75.34	10.07	34.28	4.58	61.0	80.80	10.80	49.29	6.59
.75	75.42	10.08	34.50	4.61	.25	80.89	10.81	49.55	6.62
46.0	75.51	10.09	34.73	4.64	.50	80.98	10.82	49.81	6.66
.25	75.59	10.10	34.95	4.67	.75	81.07	10.83	50.07	6.69
.50	75.67	10.11	35.18	4.70	62.0	81.17	10.85	50.33	6.73
.75	75.75	10.12	35.41	4.73	.25	81.26	10.86	50.59	6.76
47.0	75.84	10.13	35.64	4.76	.50	81.35	10.87	50.86	6.80
.25	75.93	10.14	35.87	4.79	.75	81.44	10.88	51.12	6.83
.50	76.01	10.15	36.10	4.82	63.0	81.54	10.90	51.38	6.87
.75	76.09	10.16	36.33	4.85	.25	81.63	10.91	51.64	6.90
48.0	76.18	10.18	36.56	4.89	.50	81.73	10.92	51.90	6.94
.25	76.26	10.19	36.79	4.92	.75	81.82	10.93	52.16	6.97
.50	76.35	10.20	37.02	4.95	64.0	81.92	10.95	52.43	7.01
.75	76.43	10.22	37.25	4.98	.25	82.01	10.96	52.69	7.04
49.0	76.52	10.23	37.49	5.01	.50	82.11	10.97	52.97	7.08
.25	76.60	10.24	37.72	5.04	.75	82.20	10.98	53.23	7.11
.50	76.69	10.25	37.96	5.07	65.0	82.30	11.00	53.50	7.15
.75	76.78	10.26	38.20	5.10	.25	82.39	11.01	53.77	7.18

WEIGHT PER CUBIC FOOT.—*Continued.*

Degree Brix	Weight of		Solids (Brix) per		Degree Brix	Weight of		Solids (Brix) per	
	1 cu.ft.	1 gal.	1 cu.ft.	1 gal.		1 cu.ft.	1 gal.	1 cu.ft.	1 gal.
	Lbs.	Lbs.	Lbs.	Lbs.		Lbs.	Lbs.	Lbs.	Lbs.
65.50	82.49	11.02	54.04	7.22	81.0	88.70	11.85	71.86	9.61
.75	82.58	11.03	54.31	7.25	.25	88.80	11.86	72.17	9.65
66.0	82.68	11.05	54.57	7.29	.50	88.91	11.88	72.48	9.69
.25	82.77	11.06	54.84	7.32	.75	89.02	11.89	72.79	9.73
.50	82.87	11.07	55.11	7.36	82.0	89.13	11.91	73.09	9.77
.75	82.96	11.08	55.38	7.39	.25	89.23	11.92	73.40	9.81
67.0	83.06	11.10	55.65	7.43	.50	89.34	11.94	73.71	9.85
.25	83.15	11.11	55.92	7.47	.75	89.44	11.95	74.02	9.89
.50	83.25	11.12	56.19	7.51	83.0	89.55	11.97	74.33	9.94
.75	83.35	11.13	56.46	7.55	.25	89.65	11.98	74.64	9.98
68.0	83.45	11.15	56.73	7.58	.50	89.76	11.99	74.95	10.02
.25	83.54	11.16	57.00	7.61	.75	89.86	12.00	75.26	10.06
.50	83.64	11.17	57.28	7.65	84.0	89.97	12.02	75.57	10.10
.75	83.74	11.18	57.56	7.69	.25	90.07	12.03	75.89	10.14
69.0	83.84	11.20	57.84	7.73	.50	90.18	12.05	76.20	10.18
.25	83.93	11.21	58.12	7.76	.75	90.29	12.07	76.52	10.22
.50	84.03	11.22	58.40	7.80	85.0	90.40	12.08	76.84	10.27
.75	84.12	11.23	58.68	7.84	.25	90.50	12.09	77.16	10.31
70.0	84.23	11.26	58.96	7.88	.50	90.61	12.11	77.48	10.35
.25	84.32	11.27	59.24	7.92	.75	90.72	12.12	77.80	10.40
.50	84.42	11.28	59.52	7.96	86.0	90.83	12.14	78.11	10.44
.75	84.51	11.29	59.80	8.00	.25	90.94	12.15	78.43	10.48
71.0	84.62	11.31	60.08	8.03	.50	91.04	12.17	78.75	10.52
.25	84.72	11.32	60.36	8.07	.75	91.15	12.18	79.08	10.57
.50	84.82	11.33	60.65	8.11	87.0	91.26	12.20	79.41	10.62
.75	84.92	11.34	60.93	8.15	.25	91.37	12.21	79.73	10.66
72.0	85.02	11.36	61.22	8.19	.50	91.48	12.23	80.06	10.71
.25	85.11	11.37	61.50	8.23	.75	91.59	12.24	80.38	10.75
.50	85.21	11.39	61.78	8.27	88.0	91.70	12.26	80.70	10.79
.75	85.31	11.40	62.07	8.31	.25	91.81	12.27	81.02	10.83
73.0	85.41	11.42	62.35	8.34	.50	91.92	12.28	81.34	10.88
.25	85.51	11.43	62.64	8.38	.75	92.03	12.29	81.66	10.92
.50	85.61	11.44	62.93	8.42	89.0	92.14	12.31	82.00	10.96
.75	85.71	11.45	63.22	8.46	.25	92.25	12.32	82.32	11.00
74.0	85.81	11.47	63.51	8.49	.50	92.36	12.34	82.67	11.05
.25	85.91	11.48	63.80	8.53	.75	92.47	12.35	82.99	11.09
.50	86.01	11.49	64.09	8.57	90.0	92.58	12.37	83.32	11.13
.75	86.11	11.50	64.38	8.61	.25	92.69	12.38	83.65	11.17
75.0	86.22	11.52	64.67	8.64	.50	92.80	12.40	83.99	11.22
.25	86.32	11.53	64.96	8.68	.75	92.91	12.41	84.32	11.26
.50	86.42	11.55	65.26	8.72	91.0	93.02	12.43	84.65	11.31
.75	86.52	11.56	65.55	8.76	.25	93.13	12.44	84.98	11.35
76.0	86.63	11.58	65.85	8.80	.50	93.24	12.46	85.32	11.40
.25	86.73	11.59	66.15	8.84	.75	93.35	12.47	85.56	11.44
.50	86.83	11.60	66.44	8.88	92.0	93.47	12.49	85.99	11.49
.75	86.93	11.61	66.73	8.92	.25	93.58	12.50	86.32	11.53
77.0	87.04	11.63	67.02	8.96	.50	93.69	12.52	86.66	11.58
.25	87.14	11.64	67.32	9.00	.75	93.80	12.53	87.00	11.62
.50	87.24	11.66	67.62	9.04	93.0	93.92	12.55	87.35	11.67
.75	87.34	11.67	67.92	9.08	.25	94.03	12.56	87.69	11.71
78.0	87.45	11.69	68.22	9.12	.50	94.14	12.58	88.03	11.76
.25	87.55	11.70	68.52	9.16	.75	94.25	12.59	88.37	11.80
.50	87.65	11.71	68.82	9.20	94.0	94.37	12.61	88.71	11.84
.75	87.75	11.72	69.12	9.24	.25	94.48	12.62	89.05	11.89
79.0	87.86	11.74	69.41	9.27	.50	94.60	12.64	89.40	11.94
.25	87.96	11.75	69.71	9.31	.75	94.71	12.65	89.74	11.99
.50	88.07	11.77	70.01	9.35	95.0	94.83	12.67	90.09	12.04
.75	88.17	11.78	70.31	9.39	.25	94.94	12.68	90.44	12.08
80.0	88.28	11.80	70.62	9.44	.50	95.06	12.70	90.78	12.12
.25	88.38	11.81	70.93	9.48	.75	95.17	12.71	91.13	12.17
.50	88.49	11.82	71.24	9.52	96.0	95.29	12.73	91.48	12.22
.75	88.59	11.83	71.55	9.56	.25	95.40	12.74	91.83	12.26
					.50	95.52	12.76	92.18	12.30

356. TABLE FOR THE CALCULATION OF THE WANTAGE (EMPTY SPACE) IN HORIZONTAL CYLINDRICAL TANKS (TANK CARS, CRYSTALLIZERS, ETC.), IN U. S. GALLONS AND CUBIC FEET.

(Let W = wantage; D = diameter of tank; I = depth of empty space (" inches out "); L = mean length of tank; F = area of segment, $W = (D^2 \times F \times L) \div 231$, wantage in U. S. gallons, or dividing by 1728 gives wantage in cubic feet. All dimensions are in inches.) *See* page 321.

$I+D$	F	$I+D$	F	$I+D$	F	$I+D$	F	$I+D$	F
.001	.00004	.051	.01512	.101	.04148	.151	.07459	.201	.11262
.002	.00012	.052	.01556	.102	.04208	.152	.07531	.202	.11343
.003	.00022	.053	.01601	.103	.04269	.153	.07603	.203	.11423
.004	.00034	.054	.01646	.104	.04310	.154	.07675	.204	.11503
.005	.00047	.055	.01691	.105	.04391	.155	.07747	.205	.11584
.006	.00062	.056	.01737	.106	.04452	.156	.07820	.206	.11665
.007	.00078	.057	.01783	.107	.04514	.157	.07892	.207	.11746
.008	.00095	.058	.01830	.108	.04575	.158	.07965	.208	.11827
.009	.00113	.059	.01877	.109	.04638	.159	.08038	.209	.11908
.010	.00133	.060	.01924	.110	.04700	.160	.08111	.210	.11990
.011	.00153	.061	.01972	.111	.04763	.161	.08185	.211	.12071
.012	.00175	.062	.02020	.112	.04826	.162	.08258	.212	.12153
.013	.00197	.063	.02068	.113	.04889	.163	.08332	.213	.12235
.014	.00220	.064	.02117	.114	.04953	.164	.08406	.214	.12317
.015	.00244	.065	.02165	.115	.05016	.165	.08480	.215	.12394
.016	.00268	.066	.02215	.116	.05080	.166	.08554	.216	.12481
.017	.00294	.067	.02265	.117	.05145	.167	.08629	.217	.12563
.018	.00320	.068	.02315	.118	.05209	.168	.08704	.218	.12646
.019	.00347	.069	.02336	.119	.05274	.169	.08779	.219	.12728
.020	.00375	.070	.02417	.120	.05338	.170	.08853	.220	.12811
.021	.00403	.071	.02468	.121	.05404	.171	.08929	.221	.12894
.022	.00432	.072	.02519	.122	.05469	.172	.09004	.222	.12977
.023	.00462	.073	.02571	.123	.05534	.173	.09080	.223	.13060
.024	.00492	.074	.02624	.124	.05600	.174	.09155	.224	.13144
.025	.00523	.075	.02676	.125	.05666	.175	.09231	.225	.13227
.026	.00555	.076	.02729	.126	.05733	.176	.09307	.226	.13311
.027	.00587	.077	.02782	.127	.05799	.177	.09384	.227	.13394
.028	.00619	.078	.02835	.128	.05866	.178	.09460	.228	.13478
.029	.00653	.079	.02889	.129	.05933	.179	.09537	.229	.13562
.030	.00686	.080	.02943	.130	.06000	.180	.09613	.230	.13646
.031	.00721	.081	.02997	.131	.06067	.181	.09690	.231	.13731
.032	.00756	.082	.03052	.132	.06135	.182	.09767	.232	.13815
.033	.00791	.083	.03107	.133	.06203	.183	.09845	.233	.13900
.034	.00827	.084	.03162	.134	.06271	.184	.09922	.234	.13984
.035	.00864	.085	.03218	.135	.06339	.185	.10000	.235	.14069
.036	.00901	.086	.03274	.136	.06407	.186	.10077	.236	.14154
.037	.00938	.087	.03330	.137	.06476	.187	.10155	.237	.14239
.038	.00976	.088	.03387	.138	.06545	.188	.10233	.238	.14324
.039	.01015	.089	.03444	.139	.06614	.189	.10312	.239	.14409
.040	.01054	.090	.03501	.140	.06683	.190	.10390	.240	.14494
.041	.01093	.091	.03558	.141	.06753	.191	.10468	.241	.14580
.042	.01133	.092	.03616	.142	.06822	.192	.10547	.242	.14665
.043	.01173	.093	.03674	.143	.06892	.193	.10626	.243	.14751
.044	.01214	.094	.03732	.144	.06962	.194	.10705	.244	.14837
.045	.01255	.095	.03790	.145	.07033	.195	.10784	.245	.14923
.046	.01297	.096	.03849	.146	.07103	.196	.10864	.246	.15009
.047	.01339	.097	.03908	.147	.07174	.197	.10943	.247	.15095
.048	.01382	.098	.03968	.148	.07245	.198	.11023	.248	.15182
.049	.01425	.099	.04027	.149	.07316	.199	.11102	.249	.15268
.050	.01468	.100	.04087	.150	.07387	.200	.11182	.250	.15355

CALCULATION OF WANTAGE IN CYLINDRICAL TANKS.—
Continued.

I + D	F	I + D	F	I ÷ D	F	I + D	F	I + D	F
.251	.15441	.301	.19908	.351	.24593	.401	.29435	.451	.34378
.252	.15528	.302	.20000	.352	.24689	.402	.29533	.452	.34477
.253	.15615	.303	.20092	.353	.24784	.403	.29631	.453	.34577
.254	.15702	.304	.20184	.354	.24880	.404	.29729	.454	.34676
.255	.15789	.305	.20276	.355	.24976	.405	.29827	.455	.34776
.256	.15876	.306	.20368	.356	.25071	.406	.29925	.456	.34875
.257	.15964	.307	.20460	.357	.25167	.407	.30024	.457	.34975
.258	.16051	.308	.20553	.358	.25263	.408	.30122	.458	.35075
.259	.16139	.309	.20645	.359	.25359	.409	.30220	.459	.35174
.260	.16226	.310	.20738	.360	.25455	.410	.30319	.460	.85274
.261	.16314	.311	.20830	.361	.25551	.411	.30417	.461	.35374
.262	.16402	.312	.20923	.362	.25647	.412	.30515	.462	.35474
.263	.16490	.313	.21015	.363	.25743	.413	.30614	.463	.35573
.264	.16578	.314	.21108	.364	.25839	.414	.30712	.464	.35673
.265	.16666	.315	.21201	.365	.25936	.415	.30811	.465	.35773
.266	.16755	.316	.21294	.366	.26032	.416	.30909	.466	.35872
.267	.16844	.317	.21387	.367	.26128	.417	.31008	.467	.35972
.268	.16931	.318	.21480	.368	.26225	.418	.31107	.468	.36072
.269	.17020	.319	.21573	.369	.26321	.419	.31205	.469	.36172
.270	.17109	.320	.21667	.370	.26418	.420	.31304	.470	.36272
.271	.17197	.321	.21760	.371	.26514	.421	.31403	.471	.36371
.272	.17287	.322	.21853	.372	.26611	.422	.31502	.472	.36471
.273	.17376	.323	.21947	.373	.26708	.423	.31600	.473	.36571
.274	.17465	.324	.22040	.374	.26804	.424	.31699	.474	.36671
.275	.17554	.325	.22134	.375	.26901	.425	.31798	.475	.36771
.276	.17643	.326	.22228	.376	.26998	.426	.31897	.476	.36871
.277	.17733	.327	.22321	.377	.27095	.427	.31996	.477	.36971
.278	.17822	.328	.22415	.378	.27192	.428	.32095	.478	.37071
.279	.17912	.329	.22509	.379	.27289	.429	.32194	.479	.3717
.280	.18002	.330	.22603	.380	.27386	.430	.32293	.480	.3727
.281	.18092	.331	.22697	.381	.27483	.431	.32391	.481	.3737
.282	.18182	.332	.22791	.382	.27580	.432	.32490	.482	.3747
.283	.18272	.333	.22886	.383	.27677	.433	.32590	.483	.3757
.284	.18361	.334	.22980	.384	.27775	.434	.32689	.484	.3767
.285	.18452	.335	.23074	.385	.27872	.435	.32788	.485	.3777
.286	.18542	.336	.23169	.386	.27969	.436	.32887	.486	.3787
.287	.18633	.337	.23263	.387	.28067	.437	.32987	.487	.3797
.288	.18723	.338	.23358	.388	.28164	.438	.33086	.488	.3807
.289	.18814	.339	.23453	.389	.28262	.439	.33185	.489	.3817
.290	.18905	.340	.23547	.390	.28359	.440	.33284	.490	.3827
.291	.18995	.341	.23642	.391	.28457	.441	.33384	.491	.3837
.292	.19086	.342	.23737	.392	.28554	.442	.33483	.492	.3847
.293	.19177	.343	.23832	.393	.28652	.443	.33582	.493	.3857
.294	.19268	.344	.23927	.394	.28750	.444	.33682	.494	.3867
.295	.19360	.345	.24022	.395	.28848	.445	.33781	.495	.3877
.296	.19451	.346	.24117	.396	.28945	.446	.33880	.496	.3887
.297	.19542	.347	.24212	.397	.29043	.447	.33980	.497	.3897
.298	.19634	.348	.24307	.398	.29141	.448	.34079	.498	.3907
.299	.19725	.349	.24403	.399	.29239	.449	.34179	.499	.3917
.300	.19817	.350	.24498	.400	.29337	.450	.34278	.500	.3927

367. SCHMITZ'S TABLE (RECALCULATED) FOR SUCROSE FOR USE IN HORNE'S DRY LEAD METHOD AND IN POLARIZING UNDILUTED SOLUTIONS.

(This table is arranged after Schmitz, but no allowance is made for variations in the rotatory power of sucrose. The investigations of Browne[1] show such allowance to be unnecessary.)

Degrees Brix and Per Cents Sucrose.

Pol. Reading	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
1	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
2	0.52	0.52	0.52	0.52	0.52	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.50	0.50	0.50	0.50
3	0.78	0.78	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.76	0.76	0.76	0.76	0.76	0.76	0.75	0.75	0.75
4	1.04	1.03	1.03	1.03	1.03	1.03	1.02	1.02	1.02	1.02	1.02	1.01	1.01	1.01	1.01	1.01	1.00	1.00
5	1.29	1.29	1.29	1.29	1.29	1.28	1.28	1.28	1.28	1.27	1.27	1.27	1.27	1.26	1.26	1.26	1.25	1.25
6		1.55	1.55	1.55	1.55	1.54	1.54	1.53	1.53	1.53	1.53	1.52	1.52	1.51	1.51	1.51	1.51	1.50
7		1.81	1.81	1.80	1.80	1.80	1.80	1.79	1.79	1.79	1.78	1.77	1.77	1.77	1.76	1.76	1.76	1.75
8			2.06	2.06	2.06	2.05	2.05	2.04	2.04	2.04	2.03	2.03	2.02	2.02	2.02	2.01	2.01	2.00
9				2.32	2.31	2.31	2.30	2.30	2.30	2.29	2.28	2.28	2.28	2.27	2.27	2.26	2.26	2.25
10				2.56	2.57	2.57	2.56	2.56	2.56	2.55	2.54	2.54	2.53	2.53	2.52	2.51	2.51	2.50
11				2.83	2.83	2.82	2.82	2.81	2.81	2.80	2.80	2.79	2.78	2.78	2.77	2.77	2.76	2.75
12					3.08	3.08	3.07	3.06	3.06	3.05	3.05	3.04	3.04	3.03	3.02	3.02	3.01	3.00
13					3.34	3.33	3.33	3.32	3.31	3.30	3.30	3.29	3.29	3.28	3.28	3.27	3.26	3.26
14						3.59	3.58	3.58	3.57	3.56	3.56	3.55	3.54	3.53	3.53	3.52	3.51	3.51
15						3.84	3.83	3.83	3.82	3.82	3.82	3.81	3.79	3.78	3.78	3.77	3.76	3.76
16							4.09	4.09	4.08	4.07	4.07	4.06	4.05	4.04	4.03	4.02	4.01	4.01
17								4.34	4.33	4.33	4.32	4.31	4.30	4.29	4.28	4.28	4.27	4.26
18								4.59	4.59	4.58	4.57	4.56	4.55	4.54	4.54	4.53	4.52	4.51
19									4.84	4.84	4.83	4.82	4.81	4.80	4.79	4.78	4.77	4.76
20										5.09	5.08	5.07	5.06	5.05	5.04	5.03	5.02	5.01
21										5.34	5.33	5.32	5.30	5.30	5.29	5.28	5.27	5.26
22										5.60	5.59	5.58	5.57	5.55	5.54	5.53	5.52	5.51

6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	
5.85	5.84	5.83	5.82	5.81	5.80	5.79	5.77	5.76	23
	6.10	6.09	6.07	6.06	6.05	6.04	6.02	6.01	24
	6.35	6.34	6.33	6.31	6.30	6.29	6.27	6.26	25
		6.59	6.58	6.57	6.55	6.54	6.52	6.51	26
		6.84	6.83	6.82	6.80	6.79	6.77	6.76	27
			7.08	7.07	7.05	7.04	7.03	7.02	28
			7.34	7.33	7.31	7.29	7.28	7.27	29
				7.57	**7.55**	**7.54**	**7.53**	**7.52**	**30**
				7.82	7.81	7.79	7.78	7.76	31
					8.06	8.04	8.03	8.02	32
					8.31	8.30	8.28	8.27	33
						8.55	8.53	8.52	34
							8.78	8.77	35
							9.03	9.02	36
							9.28	9.27	37
								9.51	38
								9.76	39

DEGREES BRIX FROM 0.5 TO 12.0.	
Tenths of the Polariscope Reading.	Per Cent Sucrose.
0.1	0.02
0.2	0.05
0.3	0.07
0.4	0.10
0.5	0.12
0.6	0.15
0.7	0.17
0.8	0.20
0.9	0.22

INSTRUCTIONS.

Note the Degree Brix of the solution. To an indefinite volume of the solution, contained in a narrow cylinder or other vessel that may be readily closed by the palm of the hand, add sufficient dry subacetate of lead in powder and a little dry sand; cover the mouth of the cylinder with the hand and shake to thoroughly mix the solution with the lead. Filter and polarise, using a 200-mm. tube. To the number in the table opposite the integral part of the polariscope reading and under the degree Brix nearest that observed, add the number in the small table corresponding to the tenths of the reading. The sum of these numbers is the per cent sucrose in the solution.

[1] Handbook of Sugar Analysis (John Wiley & Sons), 118.

SCHMITZ'S TABLE FOR SUCROSE (HORNE'S METHOD).—*Continued.*

DEGREES BRIX AND PER CENTS SUCROSE.

Pol. Reading	20.0	19.5	19.0	18.5	18.0	17.5	17.0	16.5	16.0	15.5	15.0	14.5	14.0	13.5	13.0	12.5	12.0	11.5	11.0	10.5
1	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
2	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
3	0.72	0.72	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.75	0.75	0.75	0.75
4	0.96	0.96	0.97	0.97	0.97	0.97	0.97	0.98	0.98	0.98	0.98	0.99	0.99	0.99	0.99	0.99	0.99	1.00	1.00	1.00
5	1.20	1.21	1.21	1.21	1.21	1.22	1.22	1.22	1.22	1.23	1.23	1.23	1.24	1.24	1.24	1.24	1.24	1.25	1.25	1.25
6	1.44	1.45	1.45	1.45	1.45	1.46	1.46	1.46	1.47	1.47	1.48	1.48	1.48	1.48	1.49	1.49	1.49	1.50	1.50	1.50
7	1.68	1.69	1.69	1.69	1.69	1.69	1.70	1.70	1.71	1.72	1.72	1.73	1.73	1.73	1.74	1.74	1.74	1.75	1.75	1.75
8	1.92	1.93	1.93	1.94	1.94	1.94	1.95	1.95	1.96	1.96	1.97	1.97	1.97	1.98	1.98	1.98	1.98	1.99	2.00	2.00
9	2.16	2.17	2.18	2.18	2.19	2.19	2.20	2.20	2.21	2.21	2.21	2.22	2.22	2.23	2.24	2.24	2.24	2.24	2.24	2.25
10	2.41	2.41	2.42	2.42	2.43	2.43	2.44	2.44	2.45	2.45	2.46	2.46	2.47	2.47	2.48	2.48	2.48	2.49	2.49	2.50
11	2.64	2.65	2.66	2.66	2.67	2.67	2.67	2.68	2.68	2.69	2.70	2.71	2.71	2.71	2.72	2.73	2.73	2.73	2.74	2.75
12	2.89	2.89	2.90	2.91	2.91	2.92	2.92	2.93	2.93	2.94	2.95	2.95	2.96	2.96	2.97	2.97	2.98	2.98	2.99	3.00
13	3.13	3.13	3.14	3.14	3.15	3.16	3.16	3.17	3.17	3.18	3.19	3.19	3.20	3.20	3.21	3.22	3.23	3.23	3.24	3.25
14	3.37	3.37	3.38	3.39	3.40	3.41	3.41	3.42	3.43	3.43	3.43	3.45	3.45	3.45	3.46	3.47	3.48	3.48	3.50	3.50
15	3.61	3.62	3.62	3.63	3.64	3.65	3.65	3.66	3.66	3.67	3.68	3.69	3.69	3.70	3.71	3.71	3.72	3.73	3.74	3.75
16	3.85	3.85	3.86	3.87	3.88	3.88	3.88	3.90	3.91	3.92	3.93	3.94	3.94	3.95	3.96	3.96	3.97	3.98	3.99	4.00
17	4.09	4.10	4.11	4.11	4.12	4.12	4.12	4.14	4.15	4.16	4.17	4.19	4.19	4.19	4.20	4.21	4.22	4.23	4.24	4.25
18	4.33	4.34	4.35	4.35	4.37	4.37	4.37	4.39	4.40	4.41	4.41	4.44	4.44	4.44	4.45	4.46	4.47	4.48	4.49	4.50
19	4.57	4.58	4.59	4.60	4.61	4.61	4.61	4.63	4.64	4.65	4.66	4.67	4.68	4.69	4.70	4.71	4.72	4.73	4.74	4.75
20	4.81	4.82	4.83	4.84	4.85	4.86	4.86	4.88	4.89	4.90	4.91	4.92	4.93	4.94	4.95	4.96	4.97	4.98	4.99	5.00
21	5.05	5.06	5.07	5.08	5.09	5.10	5.10	5.12	5.13	5.15	5.15	5.16	5.17	5.18	5.19	5.20	5.21	5.23	5.23	5.25
22	5.29	5.30	5.31	5.32	5.34	5.35	5.35	5.37	5.38	5.39	5.40	5.41	5.42	5.43	5.44	5.45	5.46	5.47	5.48	5.50
23	5.53	5.54	5.55	5.56	5.58	5.58	5.59	5.61	5.62	5.64	5.65	5.66	5.67	5.68	5.69	5.70	5.71	5.72	5.73	5.75
24	5.77	5.79	5.80	5.81	5.82	5.83	5.84	5.86	5.87	5.89	5.90	5.91	5.92	5.93	5.94	5.95	5.96	5.97	5.98	6.00
25	6.01	6.03	6.04	6.05	6.06	6.07	6.08	6.10	6.11	6.13	6.14	6.15	6.16	6.17	6.18	6.20	6.21	6.22	6.23	6.25

	10.5	11.0	11.5	12.0	12.5	13.0	13.5	14.0	14.5	15.0	15.5	16.0	16.5	17.0	17.5	18.0	18.5	19.0	19.5	20.0	
26	6.50	6.49	6.48	6.46	6.44	6.43	6.42	6.41	6.40	6.39	6.38	6.36	6.34	6.33	6.32	6.30	6.29	6.28	6.27	6.26	26
27	6.75	6.74	6.72	6.70	6.69	6.68	6.67	6.65	6.64	6.63	6.62	6.60	6.59	6.57	6.56	6.55	6.54	6.52	6.51	6.50	27
28	7.00	6.98	6.97	6.95	6.94	6.93	6.93	6.90	6.89	6.87	6.86	6.85	6.84	6.82	6.81	6.79	6.78	6.77	6.75	6.74	28
29	7.25	7.23	7.22	7.20	7.19	7.17	7.18	7.15	7.14	7.12	7.11	7.09	7.08	7.06	7.05	7.03	7.02	7.01	6.99	6.98	29
30	**7.50**	**7.48**	**7.47**	**7.45**	**7.44**	**7.42**	**7.41**	**7.40**	**7.39**	**7.37**	**7.35**	**7.34**	**7.33**	**7.31**	**7.29**	**7.27**	**7.26**	**7.25**	**7.23**	**7.22**	**30**
31	7.75	7.73	7.71	7.70	7.68	7.66	7.65	7.64	7.63	7.61	7.60	7.58	7.57	7.55	7.53	7.51	7.50	7.49	7.47	7.46	31
32	8.00	7.98	7.96	7.95	7.93	7.91	7.90	7.89	7.88	7.86	7.84	7.82	7.81	7.79	7.78	7.76	7.75	7.73	7.71	7.70	32
33	8.25	8.23	8.21	8.20	8.18	8.16	8.15	8.13	8.12	8.10	8.09	8.07	8.05	8.03	8.01	8.00	7.99	7.97	7.95	7.94	33
34	8.50	8.48	8.47	8.45	8.43	8.41	8.40	8.38	8.37	8.35	8.34	8.32	8.30	8.28	8.26	8.24	8.23	8.22	8.20	8.18	34
35	8.75	8.73	8.71	8.69	8.68	8.66	8.65	8.63	8.61	8.59	8.58	8.56	8.54	8.52	8.50	8.48	8.47	8.46	8.44	8.42	35
36	9.00	8.98	8.96	8.94	8.92	8.91	8.90	8.88	8.86	8.84	8.82	8.80	8.78	8.76	8.75	8.73	8.71	8.70	8.68	8.66	36
37	9.25	9.23	9.21	9.19	9.17	9.15	9.14	9.12	9.10	9.08	9.07	9.05	9.03	9.01	8.99	8.97	8.95	8.94	8.92	8.90	37
38	9.50	9.48	9.46	9.44	9.42	9.40	9.39	9.37	9.35	9.33	9.31	9.29	9.27	9.26	9.24	9.21	9.20	9.18	9.16	9.14	38
39	9.75	9.73	9.71	9.69	9.67	9.65	9.64	9.62	9.60	9.58	9.55	9.53	9.51	9.50	9.48	9.46	9.44	9.43	9.40	9.38	39

DEGREES BRIX FROM 0.5 TO 12.0.		DEGREES BRIX FROM 12.0 TO 20.0.	
Tenths of the Polariscope Reading.	Per Cents Sucrose.	Tenths of the Polariscope Reading.	Per Cents Sucrose.
0.1	0.02	0.1	0.02
0.2	0.05	0.2	0.05
0.3	0.07	0.3	0.07
0.4	0.10	0.4	0.10
0.5	0.12	0.5	0.12
0.6	0.15	0.6	0.15
0.7	0.17	0.7	0.17
0.8	0.20	0.8	0.19
0.9	0.22	0.9	0.22

Pol. R.	19.5	19.0	18.5	18.0	17.5	17.0	16.5	16.0	15.5	15.0	14.5	14.0	13.5	13.0	12.5	12.0	11.5	Pol. R.
40	9.64	9.66	9.68	9.70	9.72	9.74	9.76	9.78	9.80	9.82	9.84	9.86	9.88	9.90	9.92	9.94	9.96	40
41	9.88	9.90	9.92	9.94	9.96	9.98	10.00	10.02	10.04	10.06	10.08	10.10	10.12	10.15	10.17	10.18	10.20	41
42	10.12	10.14	10.16	10.18	10.20	10.22	10.24	10.26	10.29	10.31	10.33	10.35	10.37	10.40	10.43	10.43	10.45	42
43	10.36	10.38	10.41	10.42	10.44	10.47	10.49	10.51	10.53	10.56	10.58	10.60	10.62	10.65	10.67	10.68	10.70	43
44	10.60	10.63	10.65	10.67	10.69	10.72	10.74	10.76	10.78	10.81	10.83	10.85	10.87	10.89	10.92	10.93	10.95	44
45	10.85	10.87	10.89	10.91	10.93	10.96	10.98	11.00	11.02	11.05	11.07	11.09	11.11	11.14	11.16	11.18	11.20	45
46	11.08	11.11	11.14	11.16	11.18	11.20	11.22	11.24	11.27	11.30	11.32	11.34	11.36	11.39	11.41	11.43		46
47	11.33	11.35	11.37	11.40	11.42	11.44	11.47	11.49	11.51	11.54	11.56	11.59	11.61	11.63	11.66	11.67		47
48	11.56	11.59	11.62	11.64	11.66	11.69	11.72	11.74	11.76	11.79	11.81	11.84	11.86	11.89	11.90			48
49	11.80	11.83	11.86	11.88	11.90	11.93	11.96	11.98	12.00	12.03	12.05	12.08	12.10	12.13	12.15			49
50	12.05	12.08	12.10	12.13	12.15	12.18	12.20	12.23	12.25	12.28	12.30	12.33	12.35	12.38				50
51	12.29	12.32	12.34	12.37	12.39	12.42	12.44	12.47	12.49	12.52	12.54	12.57	12.60	12.63				51
52	12.53	12.56	12.58	12.62	12.63	12.67	12.69	12.71	12.74	12.77	12.79	12.82	12.85					52
53	12.77	12.80	12.83	12.86	12.87	12.91	12.93	12.96	12.99	13.01	13.04	13.07	13.09					53
54	13.01	13.04	13.07	13.11	13.12	13.15	13.18	13.20	13.24	13.26	13.29	13.32						54
55	13.25	13.28	13.31	13.34	13.36	13.39	13.42	13.44	13.48	13.50	13.53	13.56						55
56	13.50	13.52	13.55	13.58	13.61	13.64	13.66	13.69	13.73	13.75	13.78							56
57	13.74	13.76	13.79	13.82	13.85	13.88	13.90	13.93	13.97	13.99	14.02							57
58	13.98	14.01	14.04	14.07	14.09	14.12	14.15	14.18	14.21	14.24								58
59	14.22	14.25	14.28	14.31	14.33	14.36	14.39	14.42	14.45	14.48								59
60	14.46	14.49	14.52	14.55	14.58	14.61	14.64	14.67	14.70									60
61	14.70	14.73	14.76	14.79	14.82	14.85	14.88	14.91	14.95									61
62	14.94	14.97	15.00	15.04	15.07	15.10	15.13	15.16										62
63	15.18	15.21	15.24	15.28	15.31	15.34	15.37	15.40										63
64	15.43	15.46	15.49	15.53	15.56	15.59	15.62	15.65										64
65	15.67	15.70	15.73	15.77	15.80	15.83	15.86											65
66	15.91	15.94	15.97	16.01	16.04	16.07	16.10											66
67	16.15	16.18	16.21	16.25	16.28	16.31												67
68	16.39	16.43	16.46	16.49	16.52													68
69	16.63	16.67	16.70	16.73	16.77													69
70	16.87	16.91	16.94	16.98	17.01													70
71	17.11	17.15	17.18	17.22														71

DEGREES BRIX FROM 11.5 TO 22.5.

Tenths of the Polariscope Reading.	Per Cents Sucrose.
0.1	0.02
0.2	0.05
0.3	0.07
0.4	0.10
0.5	0.12
0.6	0.15
0.7	0.17
0.8	0.19
0.9	0.22

Brix, etc.

Pol. R.	19.0	19.5
72	17.39	17.35
73	17.63	17.59
74	17.87	17.83
75	18.11	18.08
76	18.35	18.32

SCHMITZ'S TABLE FOR SUCROSE (HORNE'S METHOD).—
Continued.

Pol. R'd'g	Degrees Brix and Per Cents Sucrose.									Pol. R'd'g
	20.0	20.5	21.0	21.5	22.0	22.5	23.0	23.5	24.0	
40	9.62	9.60	9.58	9.56	9.54	9.52	9.50	9.48	9.46	40
41	9.86	9.84	9.82	9.80	9.78	9.76	9.74	9.72	9.70	41
42	10.10	10.08	10.06	10.04	10.02	10.00	9.98	9.96	9.94	42
43	10.34	10.32	10.30	10.28	10.26	10.24	10.22	10.20	10.18	43
44	10.58	10.56	10.54	10.52	10.49	10.47	10.46	10.44	10.41	44
45	10.82	10.80	10.78	10.76	10.73	10.71	10.69	10.67	10.64	45
46	11.06	11.04	11.02	11.00	10.97	10.95	10.93	10.90	10.88	46
47	11.30	11.28	11.26	11.24	11.21	11.19	11.17	11.14	11.12	47
48	11.54	11.52	11.50	11.48	11.45	11.43	11.41	11.38	11.36	48
49	11.78	11.76	11.74	11.72	11.69	11.67	11.65	11.62	11.60	49
50	12.03	12.00	11.98	11.95	11.93	11.90	11.88	11.85	11.83	50
51	12.27	12.24	12.22	12.19	12.17	12.14	12.12	12.09	12.07	51
52	12.51	12.48	12.46	12.43	12.41	12.38	12.35	12.33	12.30	52
53	12.75	12.72	12.70	12.67	12.65	12.62	12.59	12.57	12.53	53
54	12.98	12.96	12.94	12.91	12.89	12.86	12.83	12.81	12.77	54
55	13.22	13.20	13.17	13.15	13.12	13.09	13.06	13.04	13.01	55
56	13.47	13.44	13.41	13.39	13.36	13.33	13.30	13.28	13.24	56
57	13.71	13.68	13.65	13.63	13.60	13.57	13.54	13.52	13.48	57
58	13.95	13.92	13.89	13.87	13.84	13.81	13.77	13.75	13.72	58
59	14.19	14.16	14.13	14.11	14.08	14.05	14.01	13.98	13.96	59
60	14.43	14.40	14.37	14.34	14.31	14.28	14.25	14.22	14.19	60
61	14.67	14.64	14.61	14.58	14.55	14.52	14.49	14.46	14.42	61
62	14.91	14.88	14.85	14.82	14.79	14.76	14.73	14.69	14.66	62
63	15.15	15.12	15.09	15.06	15.03	14.99	14.96	14.93	14.90	63
64	15.39	15.36	15.33	15.30	15.27	15.24	15.20	15.17	15.14	64
65	15.63	15.60	15.57	15.54	15.51	15.48	15.44	15.41	15.38	65
66	15.87	15.84	15.81	15.78	15.74	15.71	15.68	15.64	15.61	66
67	16.11	16.08	16.05	16.02	15.98	15.95	15.92	15.88	15.85	67
68	16.35	16.32	16.29	16.26	16.22	16.19	16.16	16.12	16.09	68
69	16.59	16.56	16.53	16.50	16.46	16.43	16.39	16.35	16.33	69
70	16.84	16.80	16.77	16.73	16.70	16.66	16.63	16.59	16.56	70
71	17.08	17.04	17.00	16.97	16.93	16.89	16.86	16.83	16.79	71
72	17.32	17.28	17.24	17.21	17.17	17.13	17.10	17.07	17.03	72
73	17.56	17.52	17.48	17.45	17.41	17.37	17.34	17.31	17.27	73
74	17.80	17.76	17.72	17.69	17.65	17.61	17.58	17.55	17.50	74
75	18.04	18.00	17.96	17.93	17.89	17.85	17.81	17.78	17.74	75
76	18.28	18.24	18.20	18.17	18.13	18.09	18.05	18.02	17.98	76
77	18.52	18.48	18.44	18.41	18.37	18.33	18.29	18.26	18.22	77
78	18.76	18.72	18.68	18.65	18.61	18.57	18.53	18.49	18.45	78
79	19.00	18.96	18.92	18.89	18.85	18.81	18.77	18.73	18.69	79
80	19.24	19.20	19.16	19.12	19.08	19.04	19.00	18.96	18.92	80
81	.....	19.44	19.40	19.36	19.32	19.28	19.24	19.20	19.16	81
82	.....	19.68	19.64	19.60	19.56	19.52	19.48	19.44	19.40	82
83	.....	.....	19.88	19.84	19.80	19.76	19.72	19.68	19.64	83
84	.....	.....	20.12	20.08	20.04	19.99	19.95	19.92	19.88	84
85	.....	.....	.....	20.32	20.28	20.23	20.19	20.15	20.10	85

DEGREES BRIX FROM 23 TO 24.

Tenths of the Polariscope Reading.	Per Cents Sucrose.	Tenths of the Polariscope Reading.	Per Cents Sucrose.
0.1	0.02	0.5	0.12
0.2	0.05	0.6	0.14
0.3	0.07	0.7	0.17
0.4	0.09	0.8	0.19
		0.9	0.21

358. SCHMITZ' TABLE FOR THE CALCULATION OF PER CENTS SUCROSE, ALLOWANCE BEING MADE FOR VARIATIONS IN THE SPECIFIC ROTATORY POWER OF CANE-SUGAR.

(CORRECTED FOR AN INCREASE IN VOLUME OF 1–10.)

Polariscopic Reading	\									Degree Brix											Polariscopic Reading
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	
1	0.29	0.29	0.29	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	1
2		0.57	0.57	0.57	0.57	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.55	0.55	0.55	0.55	0.55	0.55	2
3		0.85	0.85	0.85	0.85	0.85	0.85	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.83	0.83	0.83	0.83	0.83	0.83	3
4			1.14	1.13	1.13	1.13	1.18	1.13	1.12	1.12	1.12	1.12	1.11	1.11	1.11	1.11	1.11	1.10	1.10	1.10	4
5			1.42	1.42	1.41	1.41	1.41	1.41	1.40	1.40	1.40	1.40	1.39	1.39	1.39	1.38	1.38	1.38	1.38	1.37	5
6				1.70	1.70	1.69	1.69	1.69	1.68	1.68	1.68	1.67	1.67	1.67	1.66	1.66	1.66	1.66	1.65	1.65	6
7				1.98	1.98	1.98	1.97	1.97	1.96	1.96	1.96	1.95	1.95	1.95	1.94	1.94	1.93	1.93	1.93	1.92	7
8					2.26	2.26	2.26	2.25	2.25	2.24	2.24	2.23	2.23	2.22	2.22	2.22	2.21	2.21	2.20	2.20	8
9						2.54	2.54	2.53	2.53	2.53	2.52	2.51	2.51	2.50	2.50	2.49	2.49	2.48	2.48	2.47	9
10						2.82	2.82	2.81	2.81	2.80	2.80	2.79	2.79	2.78	2.78	2.77	2.76	2.76	2.75	2.75	10
11							3.10	3.09	3.09	3.08	3.08	3.07	3.06	3.06	3.05	3.05	3.04	3.03	3.03	3.02	11
12							3.38	3.38	3.37	3.36	3.36	3.35	3.34	3.34	3.33	3.32	3.32	3.31	3.30	3.30	12
13								3.66	3.65	3.64	3.64	3.63	3.62	3.61	3.61	3.60	3.59	3.59	3.58	3.57	13
14								3.94	3.93	3.92	3.92	3.91	3.90	3.89	3.88	3.88	3.87	3.86	3.85	3.85	14
15									4.21	4.20	4.19	4.19	4.18	4.17	4.16	4.15	4.15	4.14	4.18	4.12	15
16									4.49	4.48	4.47	4.47	4.46	4.45	4.44	4.43	4.42	4.41	4.40	4.40	16
17										4.77	4.76	4.75	4.74	4.73	4.72	4.71	4.70	4.69	4.68	4.67	17
18											4.76	5.02	5.02	5.00	4.99	4.99	4.97	4.97	4.96	4.95	18
19											5.08	5.31	5.29	5.28	5.27	5.26	5.25	5.24	5.23	5.22	19
20											5.32	5.58	5.57	5.56	5.55	5.54	5.53	5.52	5.51	5.50	20
21												5.86	5.85	5.84	5.83	5.82	5.81	5.79	5.79	5.77	21
22													6.13	6.12	6.11	6.09	6.08	6.07	6.06	6.05	22
23													6.41	6.40	6.38	6.37	6.36	6.35	6.33	6.32	23

7.0	7.5	8.0	8.5	9.0	9.5	10.0	
6.67	6.66	6.65	6.64	6.62	6.61	6.60	24
	6.94	6.98	6.91	6.90	6.89	6.87	25
	7.22	7.20	7.19	7.17	7.16	7.15	26
		7.48	7.46	7.45	7.44	7.43	27
		7.76	7.74	7.73	7.71	7.70	28
			8.02	8.00	7.99	7.97	29
				8.28	8.26	8.25	30
				8.55	8.53	8.52	31
				8.88	8.81	8.80	32
					9.09	9.07	33
						9.35	34
						9.62	35
							36
							37

DIRECTIONS FOR USING SCHMITZ' TABLE.

Note the degree Brix of the solution. Measure out 100 cc., add the lead, and dilute to 110 cc. Polarize as usual. Take the number in the table opposite the integral part of the polariscopic reading and under the degree Brix nearest that observed, and add to it the number corresponding to the tenths as shown in the small table. The sum so obtained is the per cent sucrose in the solution.

DEGREE BRIX FROM 0.5 TO 12.0.	
Tenths of the Polariscopic Reading.	Per Cent Sucrose.
0.1	0.03
0.2	0.06
0.3	0.08
0.4	0.11
0.5	0.14
0.6	0.17
0.7	0.19
0.8	0.22
0.9	0.25

SCHMITZ' TABLE FOR THE CALCULATION OF PER CENTS SUCROSE.—Continued.

DEGREE BRIX.

Polariscopic Reading	20.0	19.5	19.0	18.5	18.0	17.5	17.0	16.5	16.0	15.5	15.0	14.5	14.0	13.5	13.0	12.5	12.0	11.5	11.0	10.5
1	0.26	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.28
2	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.55	0.55	0.55	0.55
3	0.79	0.79	0.79	0.80	0.80	0.80	0.80	0.80	0.80	0.81	0.81	0.81	0.81	0.81	0.81	0.82	0.82	0.82	0.82	0.82
4	1.06	1.06	1.06	1.06	1.06	1.07	1.07	1.07	1.07	1.08	1.08	1.08	1.08	1.08	1.09	1.09	1.09	1.09	1.10	1.10
5	1.32	1.32	1.32	1.33	1.33	1.33	1.34	1.34	1.34	1.34	1.35	1.35	1.35	1.35	1.36	1.36	1.36	1.36	1.37	1.37
6	1.59	1.59	1.59	1.59	1.60	1.60	1.60	1.61	1.61	1.61	1.62	1.62	1.62	1.62	1.63	1.63	1.64	1.64	1.64	1.64
7	1.85	1.85	1.85	1.86	1.86	1.86	1.87	1.87	1.88	1.88	1.88	1.89	1.89	1.89	1.90	1.90	1.91	1.91	1.91	1.92
8	2.11	2.12	2.12	2.12	2.13	2.13	2.14	2.14	2.15	2.15	2.15	2.16	2.16	2.17	2.17	2.18	2.18	2.18	2.19	2.19
9	2.37	2.38	2.38	2.39	2.39	2.40	2.40	2.41	2.41	2.42	2.42	2.43	2.43	2.44	2.44	2.45	2.45	2.46	2.46	2.47
10	2.64	2.64	2.65	2.65	2.66	2.67	2.67	2.68	2.68	2.69	2.69	2.70	2.70	2.71	2.71	2.72	2.73	2.78	2.74	2.74
11	2.90	2.91	2.91	2.92	2.92	2.93	2.94	2.94	2.95	2.95	2.96	2.97	2.97	2.98	2.99	2.99	3.00	3.00	3.01	3.02
12	3.17	3.17	3.18	3.18	3.19	3.20	3.20	3.21	3.22	3.22	3.23	3.24	3.24	3.25	3.26	3.26	3.27	3.28	3.29	3.29
13	3.43	3.44	3.44	3.45	3.46	3.46	3.47	3.48	3.49	3.49	3.50	3.51	3.51	3.52	3.53	3.54	3.54	3.55	3.56	3.56
14	3.69	3.70	3.71	3.72	3.72	3.73	3.74	3.75	3.75	3.77	3.77	3.78	3.78	3.79	3.80	3.81	3.82	3.82	3.83	3.84
15	3.96	3.97	3.97	3.98	3.99	4.00	4.01	4.02	4.02	4.03	4.04	4.05	4.06	4.06	4.07	4.08	4.09	4.10	4.11	4.11
16	4.22	4.23	4.24	4.25	4.26	4.26	4.27	4.28	4.29	4.30	4.31	4.32	4.33	4.34	4.34	4.35	4.36	4.37	4.38	4.39
17	4.49	4.49	4.50	4.51	4.52	4.53	4.54	4.55	4.56	4.57	4.58	4.59	4.60	4.61	4.62	4.62	4.63	4.64	4.65	4.66
18	4.75	4.76	4.77	4.78	4.79	4.80	4.81	4.82	4.83	4.84	4.85	4.86	4.87	4.88	4.89	4.90	4.91	4.91	4.93	4.93
19	5.01	5.02	5.03	5.04	5.06	5.06	5.08	5.09	5.10	5.11	5.13	5.13	5.14	5.16	5.16	5.17	5.18	5.19	5.20	5.21
20	5.28	5.29	5.30	5.31	5.32	5.33	5.34	5.35	5.36	5.38	5.39	5.40	5.41	5.42	5.43	5.44	5.45	5.46	5.47	5.49
21	5.54	5.55	5.56	5.58	5.59	5.60	5.61	5.62	5.63	5.65	5.66	5.67	5.68	5.69	5.70	5.71	5.73	5.74	5.75	5.76
22	5.80	5.82	5.83	5.84	5.85	5.87	5.88	5.89	5.90	5.91	5.93	5.94	5.95	5.96	5.97	5.99	6.00	6.01	6.02	6.03
23	6.07	6.08	6.09	6.11	6.12	6.13	6.14	6.16	6.17	6.18	6.20	6.21	6.22	6.23	6.25	6.26	6.27	6.29	6.30	6.31
24	6.33	6.35	6.36	6.37	6.39	6.40	6.41	6.43	6.44	6.45	6.46	6.48	6.49	6.50	6.52	6.53	6.54	6.56	6.57	6.58
25	6.60	6.61	6.63	6.64	6.65	6.67	6.68	6.69	6.71	6.72	6.73	6.75	6.76	6.78	6.79	6.80	6.82	6.83	6.84	6.86
26	6.86	6.88	6.89	6.90	6.92	6.93	6.95	6.96	6.97	6.99	7.00	7.02	7.03	7.05	7.06	7.07	7.09	7.10	7.12	7.13

	20.0	19.5	19.0	18.5	18.0	17.5	17.0	16.5	16.0	15.5	15.0	14.5	14.0	13.5	13.0	12.5	12.0	11.5	11.0	10.5	
27	7.18	7.14	7.15	7.17	7.18	7.20	7.21	7.23	7.24	7.26	7.27	7.29	7.30	7.32	7.33	7.35	7.36	7.38	7.39	7.41	27
28	7.39	7.40	7.42	7.44	7.45	7.47	7.48	7.50	7.51	7.53	7.54	7.56	7.57	7.59	7.60	7.62	7.63	7.65	7.65	7.68	28
29	7.65	7.67	7.68	7.70	7.72	7.73	7.75	7.77	7.78	7.80	7.81	7.83	7.84	7.86	7.87	7.89	7.91	7.92	7.94	7.96	29
30	**7.92**	**7.93**	**7.95**	**7.97**	**7.98**	**8.00**	**8.02**	**8.03**	**8.05**	**8.06**	**8.08**	**8.10**	**8.11**	**8.13**	**8.15**	**8.16**	**8.18**	**8.20**	**8.21**	**8.23**	**30**
31	8.18	8.20	8.21	8.23	8.25	8.27	8.28	8.30	8.32	8.33	8.35	8.37	8.39	8.40	8.42	8.44	8.45	8.47	8.49	8.50	31
32	8.45	8.44	8.48	8.50	8.51	8.53	8.55	8.57	8.58	8.60	8.62	8.64	8.66	8.67	8.69	8.71	8.73	8.74	8.76	8.78	32
33	8.71	8.73	8.75	8.76	8.78	8.80	8.82	8.84	8.85	8.87	8.89	8.91	8.93	8.94	8.96	8.98	9.00	9.02	9.03	9.05	33
34	8.97	8.99	9.01	9.03	9.05	9.07	9.09	9.10	9.12	9.14	9.16	9.18	9.20	9.22	9.23	9.25	9.27	9.29	9.31	9.33	34
35	9.24	9.26	9.28	9.30	9.31	9.34	9.35	9.37	9.39	9.41	9.43	9.45	9.47	9.49	9.51	9.53	9.54	9.56	9.58	9.60	35
36	9.50	9.53	9.54	9.56	9.58	9.60	9.62	9.64	9.66	9.68	9.70	9.72	9.74	9.76	9.78	9.80	9.82	9.84	9.86	9.88	36
37	9.77	9.79	9.81	9.83	9.85	9.87	9.89	9.91	9.93	9.95	9.97	9.99	10.01	10.03	10.05	10.07	10.09	10.11	10.13	10.15	37
38	10.08	10.05	10.07	10.09	10.11	10.13	10.15	10.18	10.20	10.22	10.24	10.26	10.28	10.30	10.32	10.34	10.36	10.38	10.40		38
39	10.29	10.32	10.34	10.36	10.38	10.40	10.42	10.44	10.46	10.49	10.51	10.53	10.55	10.57	10.59	10.61	10.64	10.66	10.68		39

DEGREE BRIX FROM 0.5 TO 12.0.		DEGREE BRIX FROM 12.5 TO 20.0.	
Tenths of the Polariscopic Reading.	Per Cent Sucrose.	Tenths of the Polariscopic Reading.	Per Cent Sucrose.
0.1	0.03	0.1	0.03
0.2	0.06	0.2	0.05
0.3	0.08	0.3	0.08
0.4	0.11	0.4	0.11
0.5	0.14	0.5	0.13
0.6	0.17	0.6	0.16
0.7	0.19	0.7	0.19
0.8	0.22	0.8	0.21
0.9	0.25	0.9	0.24

SCHMITZ' TABLE FOR THE CALCULATION OF PER CENTS SUCROSE.—*Continued.*

Degree Brix.

Polariscopic Reading	11.5	12.0	12.5	13.0	13.5	14.0	14.5	15.0	15.5	16.0	16.5	17.0	17.5	18.0	18.5	19.0	19.5
40	10.98	10.91	10.89	10.86	10.84	10.82	10.80	10.78	10.76	10.73	10.71	10.69	10.67	10.64	10.62	10.60	10.58
41		11.18	11.16	11.14	11.12	11.09	11.07	11.05	11.03	11.00	10.98	10.96	10.94	10.91	10.89	10.87	10.85
42		11.46	11.43	11.41	11.39	11.36	11.34	11.32	11.29	11.27	11.25	11.23	11.20	11.18	11.16	11.13	11.11
43			11.71	11.68	11.66	11.64	11.61	11.59	11.56	11.54	11.52	11.49	11.47	11.45	11.42	11.40	11.38
44			11.98	11.95	11.93	11.91	11.88	11.86	11.83	11.81	11.79	11.76	11.74	11.71	11.69	11.66	11.64
45			12.25	12.23	12.20	12.18	12.15	12.13	12.10	12.08	12.05	12.03	12.01	11.98	11.96	11.93	11.91
46				12.50	12.47	12.45	12.42	12.40	12.37	12.35	12.32	12.30	12.27	12.25	12.22	12.20	12.17
47					12.74	12.72	12.69	12.67	12.64	12.61	12.59	12.56	12.54	12.51	12.49	12.46	12.44
48					13.02	12.99	12.97	12.94	12.91	12.88	12.86	12.83	12.81	12.78	12.75	12.73	12.70
49						13.26	13.23	13.21	13.18	13.15	13.13	13.10	13.07	13.05	13.02	12.99	12.97
50							13.50	13.48	13.45	13.42	13.40	13.37	13.34	13.31	13.29	13.26	13.23
51							13.78	13.75	13.72	13.69	13.66	13.64	13.61	13.58	13.55	13.52	13.50
52								14.02	13.99	13.96	13.93	13.90	13.88	13.85	13.82	13.79	13.76
53								14.29	14.26	14.23	14.20	14.17	14.14	14.11	14.08	14.06	14.03
54									14.53	14.50	14.47	14.44	14.41	14.38	14.35	14.32	14.29
55									14.80	14.77	14.74	14.71	14.68	14.65	14.62	14.59	14.56
56										15.03	15.00	14.97	14.94	14.91	14.88	14.85	14.82
57										15.30	15.27	15.24	15.21	15.18	15.15	15.12	15.09
58										15.57	15.54	15.51	15.48	15.45	15.42	15.38	15.35
59											15.81	15.78	15.75	15.71	15.68	15.65	15.62
60												16.05	16.01	15.98	15.95	15.92	15.88
61												16.31	16.28	16.25	16.21	16.18	16.15
62													16.55	16.52	16.48	16.45	16.41
63													16.82	16.78	16.75	16.71	16.68
64														17.05	17.01	16.98	16.94
65														17.31	17.28	17.24	17.21
66														17.58	17.55	17.51	17.47
67															17.81	17.78	17.74
68																18.04	18.00
69																18.31	18.27
70																	**18.68**

Degree Brix from 11.5 to 22.5.

Tenths of the Polariscopic Reading.	Per Cent Sucrose.
0.1	0.03
0.2	0.05
0.3	0.08
0.4	0.11
0.5	0.13
0.6	0.16
0.7	0.19
0.8	0.21
0.9	0.24

SCHMITZ' TABLE FOR THE CALCULATION OF PER CENTS SUCROSE.—Continued.

Polariscopic Reading	Degree Brix									Polariscopic Reading
	20.0	20.5	21.0	21.5	22.0	22.5	23.0	23.5	24.0	
40	10.56	10.54	10.52	10.49	10 47	10.45	10.43	10 41	10.38	40
41	10.82	10.80	10.78	10.76	10.74	10.71	10.69	10.67	10.65	41
42	11.09	11.07	11.04	11.02	11.00	10.97	10.95	10.93	10.90	42
43	11.35	11.33	11.31	11.28	11.26	11.24	11.21	11.19	11.17	43
44	11.62	11.59	11.57	11.55	11.52	11.50	11.47	11.45	11.42	44
45	11.88	11.86	11.83	11.81	11.78	11 76	11.73	11.71	11.69	45
46	12.15	12.12	12.09	12.07	12.05	12.02	12.00	11.97	11.94	46
47	12.41	12.39	12.36	12.33	12.31	12.28	12.26	12.23	12.21	47
48	12.67	12.65	12.62	12.60	12.57	12.54	12.52	12.49	12.47	48
49	12.94	12.91	12.88	12.86	12.83	12.81	12.78	12.75	12.73	49
50	13.20	13.18	13.15	13.12	13.09	13.07	13.04	13.01	12.99	50
51	13.47	13.44	13.41	13.39	13.36	13.33	13.30	13.27	13.25	51
52	13.73	13.70	13.68	13.65	13.62	13.59	13.56	13.53	13.51	52
53	14.00	13.97	13.94	13.91	13.88	13.85	13.82	13.79	13.77	53
54	14.26	14.23	14.20	14.17	14.14	14.11	14.08	14.06	14.02	54
55	14.53	14.50	14.47	14.44	14.41	14.38	14.35	14.32	14.29	55
56	14.79	14.76	14.73	14.70	14.67	14.64	14.61	14.58	14.55	56
57	15.06	15.02	14.99	14.96	14.93	14.90	14.87	14.84	14.81	57
58	15.32	15.29	15.26	15.23	15.19	15.16	15.13	15.10	15.07	58
59	15.58	15.55	15.52	15.49	15.46	15.42	15.39	15.36	15.33	59
60	15.85	15.82	15.78	15.75	15.72	15.69	15.65	15.62	15 59	60
61	16.11	16.08	16.05	16.01	15.98	15.95	15.91	15.88	15.85	61
62	16.38	16.35	16.31	16.28	16.24	16.21	16.18	16.14	16.11	62
63	16.64	16.61	16.57	16.54	16.51	16.47	16.44	16.40	16 37	63
64	16.91	16.87	16.84	16.80	16.77	16.73	16.70	16.66	16.63	64
65	17.17	17.14	17.10	17.07	17.03	17.00	16.96	16.92	16.89	65
66	17.44	17.40	17.37	17.33	17.29	17.26	17.22	17.19	17.15	66
67	17.70	17.67	17.63	17.59	17.56	17.52	17.48	17.45	17.41	67
68	17.97	17.93	17.89	17.86	17.82	17.78	17.74	17.71	17.67	68
69	18.23	18.19	18.16	18.12	18.08	18.04	18.00	17.97	17.93	69
70	18.50	18.46	18.42	18.38	18.35	18.31	18.27	18.23	18.19	70
71	18.76	18.72	18.68	18.65	18.61	18.57	18 53	18.49	18 45	71
72	19.03	18.99	18.95	18.91	18.87	18.83	18.79	18.75	18.71	72
73	....	19.25	19.21	19.17	19.13	19.09	19.05	19.01	18.97	73
74	....	19.52	19.48	19.44	19.40	19.35	19.31	19.27	19.23	74
75	...	19.78	19.74	19.70	19.66	19.62	19.57	19.53	19.49	75
76	....	....	20.00	19.96	19.92	19.88	19.84	19.80	19.75	76
77	....	....	20.27	20.22	20.18	20.14	20.10	20.06	20.01	77
78	....	....	....	20.49	20.45	20.40	20.36	20.32	20.27	78
79	....	....	....	20.75	20.71	20.66	20.62	20.58	20.54	79
80	....	....	....	....	20.97	20.93	20 88	20.84	20.80	80

DEGREE BRIX FROM 23 TO 24.

Tenths of the Polariscopic Reading.	Per Cent Sucrose.	Tenths of the Polariscopic Reading.	Per Cent Sucrose.
0.1	0.03	0.6	0.16
0.2	0.05	0.7	0.18
0.3	0.08	0.8	0.21
0.4	0.10	0.9	0.23
0.5	0.13		

359. TABLE FOR THE CALCULATION OF SUCROSE IN SUGAR SOLUTIONS.—(DR. CHAS. A. CRAMPTON)

(Take 50 cc. sugar solution; clarify, dilute to 100 cc. and polarize in a 200-mm. tube; multiply the reading by the factor corresponding to the density of the solution to obtain the per cent sucrose.)

Degree Brix.	Specific gravity.	Sucrose factor for instruments requiring—		Degree Brix.	Specific Gravity.	Sucrose factor for instruments requiring—	
		26.048 grams.	* 16.3 grams.			26.048 grams.	* 16.3 grams.
5.0	1.0197	.5109	.3197	9.5	1.0380	.5019	.3141
5.1	1.0201	.5107	.3196	9.6	1.0384	.5017	.3140
5.2	1.0205	.5105	.3195	9.7	1.0388	.5015	.3138
5.3	1.0209	.5108	.3193	9.8	1.0393	.5013	.3137
5 4	1.0213	.5101	.3192	9.9	1.0397	.5011	.3136
5.5	1.0217	.5099	.3191	10.0	1 0401	.5009	.3134
5.6	1.0221	.5097	.3190	10.1	1.0405	.5007	.3133
5.7	1.0225	.5095	.3189	10.2	1.0409	.5005	.3132
5.8	1.0229	.5093	.3187	10.3	1.0413	.5003	.3131
5.9	1.0233	.5091	.3186	10.4	1.0418	.5001	.3129
6.0	1.0237	.5089	.3185	10.5	1.0422	.4999	.3128
6.1	1.0241	.5087	.3184	10.6	1.0426	.4997	.3127
6.2	1.0245	.5085	.3183	10.7	1.0430	.4995	.3126
6.3	1.0249	.5083	.3182	10.8	1.0434	.4993	.3125
6.4	1.0253	.5081	.3181	10.9	1.0439	.4991	.3123
6.5	1.0257	.5079	.3180	11.0	1.0443	.4989	.3122
6.6	1.0261	.5077	.3178	11.1	1.0447	.4987	.3121
6.7	1.0265	.5075	.3177	11.2	1.0451	.4985	.3119
6.8	1.0269	.5073	.3175	11 3	1.0455	.4983	.3118
6.9	1.0273	.5071	.3174	11.4	1.0459	4981	.3117
7 0	1.0277	.5069	.3173	11.5	1.0464	.4979	.3115
7 1	1.0281	.5067	.3171	11.6	1 0468	.4977	.3114
7.2	1.0286	.5065	.3170	11.7	1.0472	.4975	.3113
7.3	1.0290	.5063	.3169	11.8	1.0476	.4973	.3112
7.4	1.0294	.5061	.3167	11.9	1.0481	.4971	.3110
7.5	1.0298	.5059	.3166	12 0	1.0485	.4969	.3109
7 6	1.0302	.5057	.3164	12.1	1.0489	.4967	.3108
7.7	1.0306	.5055	.3163	12.2	1.0493	.4965	.3107
7.8	1.0310	.5053	.3162	12 3	1.0497	.4963	.3106
7.9	1.0314	.5051	.3160	12 4	1.0502	.4961	.3104
8 0	1.0318	.5049	.3159	12 5	1.0506	.4959	.3103
8.1	1.0322	.5047	.3158	12.6	1.0510	.4957	.3102
8.2	1.0327	.5045	.3157	12.7	1.0514	.4955	.3101
8.3	1.0331	.5043	.3156	12.8	1.0519	.4953	.3099
8.4	1.0335	.5041	.3154	12.9	1.0523	.4951	.3098
8.5	1.0339	.5039	.3153	13.0	1.0527	.4949	.3097
8.6	1.0343	.5037	.3152	13.1	1.0531	.4947	.3096
8.7	1 0347	.5035	.3151	13.2	1 0536	.4945	.3094
8.8	1.0351	.5033	.3150	13.3	1.0540	.4943	.3093
8.9	1.0355	.5031	.3148	13 4	1.0544	.4941	.3092
9.0	1.0359	.5029	.3147	13.5	1 0548	.4939	.3091
9.1	1.0364	.5027	.3146	13.6	1.0553	.4937	.3090
9.2	1.0368	.5025	.3144	13.7	1.0557	.4935	.3088
9.3	1.0372	.5023	.3143	13.8	1.0561	.4933	.3087
9 4	1.0376	.5021	.3142	13.9	1.0566	.4931	.3085

* Factor for Laurent instruments graduated by means of a quartz plate 1 mm. thick. Polariscopes of this make should be tested to determine the factor.

TABLE FOR THE CALCULATION OF SUCROSE.—*Continued.*

Degree Brix.	Specific Gravity.	Sucrose factor for instruments requiring—		Degree Brix.	Specific Gravity.	Sucrose factor for instruments requiring—	
		26.048 grams.	*16.3 grams.			26.048 grams.	*16.3 grams.
14.0	1.0570	.4929	.3084	18.9	1.0783	.4831	.3023
14.1	1.0574	.4927	.3083	19.0	1.0788	.4829	.3022
14.2	1.0578	.4925	.3082	19.1	1.0792	.4827	.3021
14.3	1.0583	.4923	.3080	19.2	1.0797	.4825	.3019
14.4	1.0587	.4921	.3079	19.3	1.0801	.4823	.3018
14.5	1.0591	.4919	.3078	19.4	1.0806	.4821	.3017
14.6	1.0596	.4917	.3077	19.5	1.0810	.4819	.3016
14.7	1.0600	.4915	.3076	19.6	1.0815	.4817	.3014
14.8	1.0604	.4913	.3074	19.7	1.0819	.4815	.3013
14.9	1.0609	.4911	.3073	19.8	1.0824	.4813	.3012
15.0	1.0613	.4909	.3072	19.9	1.0828	.4811	.3011
15.1	1.0617	.4907	.3071	20.0	1.0832	.4809	.3009
15.2	1.0621	.4905	.3069	20.1	1.0837	.4807	.3008
15.3	1.0626	.4903	.3068	20.2	1.0841	.4805	.3007
15.4	1.0630	.4901	.3067	20.3	1.0846	.4803	.3006
15.5	1.0634	.4899	.3066	20.4	1.0850	.4801	.3005
15.6	1.0639	.4897	.3064	20.5	1.0855	.4798	.3003
15.7	1.0643	.4895	.3063	20.6	1.0859	.4797	.3002
15.8	1.0647	.4893	.3062	20.7	1.0864	.4795	.3001
15.9	1.0652	.4891	.3061	20.8	1.0868	.4794	.3000
16.0	1.0656	.4889	.3059	20.9	1.0873	.4791	.2998
16.1	1.0660	.4887	.3058	21.0	1.0877	.4790	.2997
16.2	1.0665	.4885	.3057	21.1	1.0882	.4787	.2996
16.3	1.0669	.4883	.3056	21.2	1.0886	.4786	.2995
16.4	1.0674	.4881	.3054	21.3	1.0891	.4788	.2993
16.5	1.0678	.4879	.3053	21.4	1.0895	.4782	.2992
16.6	1.0682	.4877	.3052	21.5	1.0900	.4779	.2991
16.7	1.0687	.4875	.3051	21.6	1.0904	.4778	.2990
16.8	1.0691	.4873	.3049	21.7	1.0909	.4775	.2988
16.9	1.0695	.4871	.3048	21.8	1.0914	.4773	.2987
17.0	1.0700	.4869	.3047	21.9	1.0918	.4772	.2986
17.1	1.0704	.4867	.3046	22.0	1.0923	.4769	.2984
17.2	1.0709	.4865	.3044	22.1	1.0927	.4768	.2983
17.3	1.0713	.4863	.3043	22.2	1.0932	.4765	.2982
17.4	1.0717	.4861	.3042	22.3	1.0936	.4764	.2981
17.5	1.0722	.4859	.3041	22.4	1.0941	.4762	.2980
17.6	1.0726	.4857	.3039	22.5	1.0945	.4760	.2979
17.7	1.0730	.4855	.3038	22.6	1.0950	.4758	.2977
17.8	1.0735	.4853	.3037	22.7	1.0954	.4756	.2976
17.9	1.0739	.4851	.3036	22.8	1.0959	.4754	.2974
18.0	1.0744	.4849	.3034	22.9	1.0964	.4752	.2973
18.1	1.0748	.4847	.3033	23.0	1.0968	.4750	.2972
18.2	1.0753	.4845	.3032	23.1	1.0973	.4748	.2971
18.3	1.0757	.4843	.3031	23.2	1.0977	.4746	.2970
18.4	1.0761	.4841	.3029	23.3	1.0982	.4744	.2968
18.5	1.0766	.4839	.3028	23.4	1.0986	.4742	.2967
18.6	1.0770	.4837	.3027	23.5	1.0991	.4740	.2966
18.7	1.0775	.4835	.3026	23.6	1.0996	.4738	.2965
18.8	1.0779	.4833	.3024	23.7	1.1100	.4736	.2963

* Factor for Laurent instruments graduated by means of a quartz plate 1 mm. thick. Polariscopes of this make should be tested to determine the factor.

360. AVAILABLE SUGAR TABLES.[1]

Values of the factor $1.4 - \dfrac{40}{\text{Coefficient purity}} \times 100$, for coefficients of purity ranging from 77 to 93, advancing by tenths. *See* page 305 for suggestions relative to the use of these tables.

(A) SUCROSE.

Purity Coeff.	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
77	88.05	88.12	88.19	88.25	88.32	88.39	88.45	88.52	88.59	88.65
78	88.72	88.78	88.85	88.92	88.98	89.04	89.11	89.18	89.24	89.31
79	89.37	89.43	89.50	89.56	89.63	89.69	89.75	89.81	89.88	89.94
80	90.00	90.07	90.13	90.19	90.25	90.32	90.38	90.44	90.50	90.56
81	90.62	90.68	90.74	90.80	90.86	90.92	90.98	91.04	91.10	91.18
82	91.22	91.28	91.34	91.39	91.45	91.51	91.57	91.63	91.69	91.75
83	91.81	91.87	91.93	91.99	92.04	92.10	92.15	92.21	92.27	92.32
84	92.38	92.44	92.50	92.55	92.61	92.67	92.72	92.78	92.84	92.89
85	92.94	93.00	93.06	93.11	93.16	93.22	93.28	93.33	93.38	93.43
86	93.49	93.54	93.59	93.64	93.70	93.75	93.80	93.85	93.91	93.97
87	94.02	94.07	94.12	94.18	94.23	94.28	94.34	94.39	94.44	94.49
88	94.55	94.60	94.65	94.70	94.76	94.81	94.86	94.91	94.95	95.01
89	95.06	95.11	95.16	95.21	95.26	95.31	95.36	95.41	95.46	95.51
90	95.56	95.61	95.65	95.70	95.75	95.80	95.85	95.90	95.95	96.00
91	96.04	96.09	96.14	96.18	96.23	96.28	96.33	96.37	96.42	96.47
92	96.52	96.57	96.62	96.67	96.71	96.75	96.80	96.85	96.90	96.95
93	96.99	97.04	97.08	97.13	97.17	97.22	97.27	97.31	97.35	97.40

[1] Methods of Chemical Control, H. C. Prinsen Geerligs. (Section "A" only.)

AVAILABLE SUGAR TABLES.—*Continued.*

(B) 96° Sugar.—(Numbers of preceding table divided by 0.96.)

Purity Coeff.	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
77	91.72	91.79	91.86	91.93	92.00	92.07	92.14	92.21	92.28	92.35
78	92.42	92.49	92.56	92.63	92.69	92.75	92.82	92.89	92.96	93.03
79	93.10	93.16	93.23	93.29	93.35	93.42	93.49	93.55	93.62	93.68
80	93.75	93.81	93.88	93.94	94.01	94.07	94.14	94.21	94.27	94.34
81	94.40	94.46	94.53	94.59	94.65	94.71	94.77	94.84	94.90	94.96
82	95.02	95.08	95.15	95.21	95.27	95.34	95.40	95.46	95.52	95.58
83	95.64	95.70	95.76	95.83	95.89	95.95	96.00	96.06	96.12	96.18
84	96.23	96.29	96.35	96.40	96.46	96.52	96.58	96.64	96.70	96.76
85	96.82	96.87	96.93	96.99	97.05	97.11	97.17	97.22	97.27	97.32
86	97.38	97.43	97.48	97.54	97.60	97.65	97.71	97.77	97.83	97.89
87	97.94	97.99	98.05	98.11	98.16	98.22	98.28	98.33	98.39	98.44
88	98.49	98.54	98.60	98.65	98.70	98.75	98.81	98.87	98.92	98.97
89	99.02	99.07	99.12	99.17	99.23	99.28	99.33	99.38	99.44	99.49
90	99.54	99.60	99.65	99.70	99.75	99.80	99.85	99.90	99.95	100.00
91	100.05	100.10	100.15	100.20	100.25	100.29	100.34	100.39	100.44	100.49
92	100.54	100.59	100.64	100.68	100.73	100.78	100.83	100.88	100.93	100.98
93	101.03	101.08	101.12	101.17	101.22	101.27	101.32	101.38	101.44	101.49

361. *RECIPROCALS OF NUMBERS FROM 11 TO 36, ADVANCING BY TENTHS.

Number.	Reciprocal.	Number.	Reciprocal.	Number.	Reciprocal.	Number.	Reciprocal.	Number.	Reciprocal.
11.0	.0909	16.0	.0625	21.0	.0476	26.0	.0385	31.0	.0322
11.1	.0900	16.1	.0621	21.1	.0474	26.1	.0383	31.1	.0321
11.2	.0893	16.2	.0617	21.2	.0472	26.2	.0381	31.2	.0320
11.3	.0885	16.3	.0613	21.3	.0469	26.3	.0380	31.3	.0319
11.4	.0877	16.4	.0610	21.4	.0467	26.4	.0379	31.4	.0318
11.5	.0869	16.5	.0606	21.5	.0465	26.5	.0377	31.5	.0317
11.6	.0862	16.6	.0602	21.6	.0463	26.6	.0316	31.6	.0316
11.7	.0855	16.7	.0599	21.7	.0461	26.7	.0374	31.7	.0315
11.8	.0847	16.8	.0595	21.8	.0459	26.8	.0373	31.8	.0314
11.9	.0840	16.9	.0592	21.9	.0457	26.9	.0372	31.9	.0313
12.0	.0833	17.0	.0588	22.0	.0454	27.0	.0370	32.0	.0312
12.1	.0826	17.1	.0585	22.1	.0452	27.1	.0369	32.1	.0311
12.2	.0820	17.2	.0581	22.2	.0450	27.2	.0368	32.2	.0310
12.3	.0813	17.3	.0578	22.3	.0448	27.3	.0366	32.3	.0309
12.4	.0806	17.4	.0575	22.4	.0446	27.4	.0365	32.4	.0308
12.5	.0800	17.5	.0571	22.5	.0444	27.5	.0364	32.5	.0308
12.6	.0794	17.6	.0568	22.6	.0442	27.6	.0362	32.6	.0307
12.7	.0787	17.7	.0565	22.7	.0440	27.7	.0361	32.7	.0305
12.8	.0781	17.8	.0562	22.8	.0438	27.8	.0360	32.8	.0305
12.9	.0775	17.9	.0559	22.9	.0437	27.9	.0358	32.9	.0304
13.0	.0769	18.0	.0555	23.0	.0435	28.0	.0357	33.0	.0303
13.1	.0763	18.1	.0552	23.1	.0432	28.1	.0356	33.1	.0302
13.2	.0757	18.2	.0549	23.2	.0431	28.2	.0355	33.2	.0301
13.3	.0752	18.3	.0546	23.3	.0429	28.3	.0353	33.3	.0300
13.4	.0746	18.4	.0543	23.4	.0427	28.4	.0352	33.4	.0299
13.5	.0741	18.5	.0540	23.5	.0425	28.5	.0351	33.5	.0298
13.6	.0735	18.6	.0538	23.6	.0424	28.6	.0350	33.6	.0297
13.7	.0730	18.7	.0535	23.7	.0422	28.7	.0348	33.7	.0296
13.8	.0725	18.8	.0532	23.8	.0420	28.8	.0347	33.8	.0295
13.9	.0719	18.9	.0529	23.9	.0418	28.9	.0346	33.9	.0295
14.0	.0714	19.0	.0526	24.0	.0417	29.0	.0345	34.0	.0294
14.1	.0709	19.1	.0523	24.1	.0415	29.1	.0344	34.1	.0293
14.2	.0704	19.2	.0521	24.2	.0413	29.2	.0342	34.2	.0292
14.3	.0699	19.3	.0518	24.3	.0411	29.3	.0341	34.3	.0291
14.4	.0694	19.4	.0515	24.4	.0409	29.4	.0340	34.4	.0290
14.5	.0690	19.5	.0513	24.5	.0408	29.5	.0339	34.5	.0289
14.6	.0685	19.6	.0510	24.6	.0406	29.6	.0338	34.6	.0289
14.7	.0680	19.7	.0508	24.7	.0405	29.7	.0337	34.7	.0288
14.8	.0676	19.8	.0505	24.8	.0403	29.8	.0335	34.8	.0287
14.9	.0671	19.9	.0503	24.9	.0402	29.9	.0334	34.9	.0286
15.0	.0667	20.0	.0500	25.0	.0400	30.0	.0333	35.0	.0285
15.1	.0662	20.1	.0497	25.1	.0398	30.1	.0332	35.1	.0284
15.2	.0658	20.2	.0495	25.2	.0397	30.2	.0331	35.2	.0284
15.3	.0654	20.3	.0493	25.3	.0395	30.3	.0330	35.3	.0283
15.4	.0649	20.4	.0490	25.4	.0394	30.4	.0329	35.4	.0282
15.5	.0645	20.5	.0488	25.5	.0392	30.5	.0328	35.5	.0282
15.6	.0641	20.6	.0485	25.6	.0391	30.6	.0327	35.6	.0281
15.7	.0637	20.7	.0483	25.7	.0389	30.7	.0326	35.7	.0280
15.8	.0633	20.8	.0481	25.8	.0388	30.8	.0325	35.8	.0279
15.9	.0629	20.9	.0478	25.9	.0386	30.9	.0324	35.9	.0278

* See page 250 for suggestions relative to the use of this table.

362. EXPANDED MEISSL-HILLER TABLE FOR INVERT SUGAR.[1]
(By E. W. Rice.)

Wt. of Sample in 100 cc.	Wt. Obtained as		Polarization									
			1 Gram		2 Grams		5 Grams		10 Grams		20 Grams	
Cu	CuO	CuO	30°	35°	20°	30°	85°	95°	85°	95°	85°	95°
.0999	.1125	.1250	10.28	10.26	5.13	5.12	1.661	1.600	.76	.76		
.1019	.1147	.1275	10.48	10.46	5.24	5.23	1.708	1.648	.78	.78		
.1039	.1170	.1300	10.69	10.67	5.34	5.33	1.755	1.696	.80	.80		
.1059	.1192	.1325	10.89	10.87	5.44	5.43	1.802	1.744	.82	.82		
.1070	.1215	.1350	11.10	11.08	5.54	5.53	1.849	1.792	.84	.84		
.1099	.1237	.1375	11.31	11.29	5.65	5.63	1.896	1.839	.86	.86		
.1119	.1260	.1400	11.52	11.50	5.76	5.74	1.942	1.886	.88	.88		
.1138	.1282	.1425	11.73	11.71	5.86	5.84	1.989	1.933	.90	.90		
.1158	.1305	.1450	11.94	11.92	5.96	5.95	2.036	1.980	.92	.92		
.1178	.1327	.1475	12.15	12.13	6.07	6.05	2.082	2.027	.94	.94		
.1198	.1350	.1500	12.36	12.34	6.18	6.16	2.128	2.074	.96	.96		
.1218	.1372	.1525	12.57	12.55	6.28	6.26	2.175	2.121	.98	.98		
.1238	.1395	.1550	12.78	12.76	6.38	6.36	2.221	2.168	1.00	1.00		
.1258	.1417	.1575	12.99	12.97	6.49	6.47	2.267	2.215	1.02	1.02		
.1278	.1440	.1600	13.21	13.19	6.60	6.58	2.313	2.262	1.05	1.04		
.1298	.1462	.1625	13.42	13.40	6.70	6.68	2.359	2.309	1.07	1.06		
.1318	.1485	.1650	13.64	13.62	6.81	6.79	2.405	2.356	1.09	1.08		
.1338	.1507	.1675	13.85	13.83	6.92	6.90	2.451	2.403	1.11	1.10		
.1358	.1530	.1700	14.07	14.05	7.03	7.01	2.497	2.449	1.13	1.12		
.1378	.1552	.1725	14.28	14.26	7.13	7.11	2.543	2.496	1.15	1.14		
.1398	.1575	.1750	14.50	14.48	7.24	7.22	2.589	2.543	1.17	1.16		
.1418	.1597	.1775	14.72	14.69	7.35	7.33	2.635	2.589	1.19	1.18		
.1438	.1620	.1800	14.93	14.91	7.46	7.44	2.680	2.635	1.22	1.21		

[1] 8th Int. Cong. App. Chemistry, 8, 47.

EXPANDED MEISSEL-HILLER TABLE.—Continued.

Wt. of Sample in 100 cc.			1 Gram.		2 Grams.		5 Grams.		10 Grams.		20 Grams.	
Polarisation.			30°	35°	20°	30°	85°	95°	85°	95°	85°	95°
Wt. Obtained as												
Cu	CuO	Cu2O										
.1458	.1642	.1825	15.15	15.12	7.56	7.54	2.726	2.682	1.24	1.23		
.1478	.1665	.1850	15.37	15.34	7.67	7.65	2.772	2.728	1.27	1.25		
.1498	.1687	.1875	15.59	15.56	7.78	7.76	2.817	2.774	1.29	1.27		
.1518	.1710	.1900	15.81	15.78	7.89	7.87	2.862	2.820	1.31	1.30		
.1538	.1732	.1925	16.03	16.00	7.99	7.97	2.907	2.867	1.33	1.32		
.1558	.1755	.1950	16.25	16.22	8.10	8.08	2.952	2.913	1.35	1.34		
.1578	.1777	.1975	16.47	16.44	8.21	8.19	2.997	2.959	1.37	1.36		
.1598	.1800	.2000	16.69	16.66	8.32	8.30	3.042	3.005	1.40	1.38		
.1618	.1822	.2025	16.91	16.88	8.43	8.40	3.087	3.051	1.42	1.40		
.1638	.1845	.2050	17.13	17.10	8.54	8.51	3.132	3.097	1.44	1.42		
.1658	.1867	.2075	17.35	17.32	8.65	8.62	3.177	3.143	1.46	1.44		
.1678	.1890	.2100	17.57	17.54	8.76	8.73	3.221	3.188	1.49	1.47		
.1698	.1912	.2125	17.79	17.76	8.87	8.83	3.266	3.234	1.51	1.49		
.1718	.1935	.2150	18.01	17.98	8.98	8.94	3.310	3.280	1.53	1.51	.72	
.1738	.1957	.2175	18.23	18.20	9.09	9.05	3.354	3.325	1.55	1.53	.73	
.1758	.1980	.2200	18.45	18.42	9.20	9.16	3.398	3.370	1.58	1.56	.75	
.1778	.2002	.2225	18.67	18.64	9.31	9.26	3.433	3.416	1.60	1.58	.76	
.1798	.2025	.2250	18.89	18.86	9.42	9.37	3.488	3.461	1.62	1.60	.77	
.1817	.2047	.2275	19.11	19.08	9.53	9.48	3.532	3.506	1.64	1.62	.78	
.1837	.2070	.2300	19.34	19.30	9.64	9.59	3.576	3.551	1.67	1.65	.79	
.1857	.2092	.2325	19.56	19.52	9.75	9.70	3.621	3.597	1.69	1.67	.80	
.1877	.2115	.2350	19.78	19.74	9.86	9.81	3.666	3.642	1.71	1.69	.81	
.1897	.2137	.2375	20.00	19.96	9.97	9.92	3.710	3.687	1.73	1.72	.82	.81
.1917	.2160	.2400	20.23	20.19	10.08	10.03	3.754	3.732	1.76	1.75	.83	.83
.1937	.2182	.2425	20.45	20.41	10.19	10.14	3.799	3.777	1.78	1.77	.84	.84
.1957	.2205	.2450	20.67	20.63	10.30	10.25	3.844	3.822	1.80	1.79	.85	.85

EXPANDED MEISSL-HILLER TABLE FOR INVERT SUGAR.—*Continued.*

Wt. of Sample in 100 cc.			1 Gram.		2 Grams.		5 Grams.		10 Grams.		20 Grams.	
Polarisation			30°	35°	20°	30°	85°	95°	85°	95°	85°	95°
Wt. Obtained as												
Cu	CuO	CuO										
.1977	.2227	.2475	20.89	20.85	10.41	10.36	3.888	3.867	1.83	1.81		
.1997	.2250	.2500	21.12	21.08	10.52	10.47	3.932	3.912	1.86	1.84	.86	.86
.2017	.2272	.2525	21.34	21.30	10.63	10.58	3.977	3.957	1.88	1.86	.88	.87
.2037	.2295	.2550	21.56	21.52	10.74	10.69	4.022	4.002	1.90	1.88	.89	.88
.2057	.2317	.2575	21.78	21.74	10.85	10.80	4.066	4.047	1.92	1.90	.90	.89
.2077	.2340	.2600	22.00	21.96	10.96	10.91	4.110	4.092	1.95	1.93	.91	.90
.2097	.2362	.2625	22.22	22.18	11.07	11.02	4.155	4.137	1.97	1.95	.92	.91
.2117	.2385	.2650	22.44	22.40	11.18	11.13	4.200	4.182	1.99	1.97	.93	.92
.2137	.2407	.2675	22.66	22.62	11.29	11.24	4.244	4.227	2.02	1.99	.94	.93
.2157	.2430	.2700	22.89	22.85	11.40	11.35	4.288	4.271	2.05	2.02	.95	.94
.2177	.2452	.2725	23.11	23.07	11.51	11.46	4.333	4.316	2.07	2.04	.97	.96
.2197	.2475	.2750	23.33	23.29	11.62	11.57	4.378	4.361	2.09	2.06	.98	.97
.2217	.2497	.2775	23.55	23.51	11.73	11.68	4.422	4.405	2.11	2.08	.99	.98
.2237	.2520	.2800	23.78	23.74	11.84	11.79	4.466	4.449	2.14	2.12	1.00	.99
.2257	.2542	.2825	24.00	23.96	11.95	11.90	4.511	4.494	2.16	2.14	1.01	1.00
.2277	.2565	.2850	24.22	24.18	12.06	12.01	4.556	4.538	2.18	2.16	1.02	1.01
.2297	.2587	.2875	24.44	24.40	12.17	12.12	4.600	4.582	2.20	2.18	1.03	1.02
.2317	.2610	.2900	24.67	24.63	12.28	12.23	4.644	4.626	2.23	2.21	1.04	1.03
.2337	.2633	.2925	24.89	24.85	12.39	12.34	4.689	4.671	2.25	2.23	1.06	1.05
.2357	.2655	.2950	25.11	25.07	12.50	12.45	4.734	4.716	2.27	2.25	1.07	1.06
.2377	.2677	.2975	25.33	25.29	12.61	12.56	4.779	4.761	2.29	2.27	1.08	1.07
.2397	.2700	.3000	25.56	25.52	12.73	12.67	4.823	4.805	2.32	2.30	1.09	1.08
.2417	.2722	.3025	25.78	25.74	12.84	12.78	4.868	4.850	2.34	2.32	1.10	1.09
.2437	.2745	.3050	26.00	25.96	12.95	12.89	4.913	4.895	2.36	2.34	1.11	1.10
.2457	.2767	.3075	26.22	26.18	13.06	13.00	4.958	4.940	2.39	2.37	1.12	1.11
.2477	.2790	.3100	26.45	26.41	13.18	13.11	5.003	4.985	2.42	2.40	1.13	1.12
											1.15	1.14

EXPANDED MEISSL-HILLER TABLE.—*Continued.*

Wt. of Sample in 100 cc.			1 Gram.		2 Grams.		5 Grams.		10 Grams.		20 Grams.	
Cu	CuO	CuO	30°	35°	20°	30°	85°	95°	85°	95°	85°	95°
.2497	.2812	.3125	26.67	26.63	13.29	13.22	5.049	5.031	2.44	2.42	1.16	1.15
.2517	.2835	.3150	26.90	26.85	13.40	13.33	5.095	5.076	2.46	2.44	1.17	1.16
.2537	.2857	.3175	27.12	27.07	13.51	13.44	5.141	5.121	2.48	2.46	1.18	1.17
.2556	.2880	.3200	27.35	27.30	13.63	13.56	5.186	5.166	2.51	2.49	1.19	1.18
.2576	.2902	.3225	27.57	27.52	13.74	13.67	5.232	5.212	2.53	2.51	1.20	1.19
.2596	.2925	.3250	27.80	27.75	13.85	13.78	5.278	5.258	2.55	2.53	1.21	1.20
.2616	.2947	.3275	28.02	27.97	13.96	13.89	5.324	5.303	2.57	2.55	1.22	1.21
.2636	.2970	.3300	28.25	28.20	14.08	14.01	5.371	5.348	2.60	2.58	1.24	1.23
.2656	.2992	.3325	28.47	28.42	14.19	14.12	5.418	5.394	2.62	2.60	1.25	1.24
.2676	.3015	.3350	28.70	28.65	14.30	14.23	5.465	5.440	2.64	2.62	1.26	1.25
.2696	.3037	.3375	28.93	28.87	14.42	14.35	5.512	5.486	2.66	2.64	1.27	1.26
.2716	.3060	.3400	29.16	29.10	14.54	14.47	5.558	5.532	2.69	2.67	1.28	1.27
.2736	.3082	.3425	29.39	29.32	14.65	14.59	5.605	5.578	2.71	2.69	1.29	1.28
.2756	.3105	.3450	29.62	29.55	14.76	14.70	5.652	5.624	2.73	2.71	1.30	1.29
.2776	.3127	.3475	29.85	29.77	14.88	14.81	5.699	5.671	2.75	2.73	1.31	1.30
.2796	.3150	.3500	30.08	30.00	15.00	14.93	5.746	5.718	2.78	2.76	1.33	1.32
.2816	.3172	.3525	30.31	30.23	15.11	15.04	5.793	5.765	2.80	2.78	1.34	1.33
.2836	.3195	.3550	30.54	30.46	15.22	15.15	5.840	5.812	2.82	2.80	1.35	1.34
.2856	.3217	.3575	30.77	30.69	15.34	15.27	5.888	5.859	2.84	2.82	1.36	1.35
.2876	.3240	.3600	31.00	30.93	15.46	15.39	5.936	5.906	2.87	2.85	1.37	1.36
.2896	.3262	.3625	31.23	31.16	15.57	15.50	5.983	5.953	2.89	2.87	1.38	1.37
.2916	.3285	.3650	31.46	31.40	15.69	15.61	6.031	6.000	2.91	2.88	1.39	1.38
.2936	.3307	.3675	31.69	31.63	15.81	15.73	6.079	6.048	2.93	2.91	1.40	1.39
.2956	.3330	.3700	31.93	31.87	15.93	15.85	6.127	6.096	2.96	2.94	1.42	1.41
.2976	.3352	.3725	32.16	32.10	16.04	15.96	6.174	6.144	2.98	2.96	1.43	1.42
.2996	.3375	.3750	32.40	32.34	16.16	16.08	6.222	6.192	3.00	2.98	1.44	1.43

EXPANDED MEISSL-HILLER TABLE.—*Continued.*

| Wt. of Sample in 100 cc. | | | 1 Gram. | | 2 Grams. | | 5 Grams. | | 10 Grams. | | 20 Grams. | |
| Polarisation. | Wt. Obtained as | | | | | | | | | | | |
Cu	CuO	CuO	30°	35°	20°	30°	85°	95°	85°	95°	85°	95°
.3016	.3397	.3775	32.63	32.67	16.28	16.20	6.270	6.240	3.03	3.00	1.45	1.44
.3036	.3420	.3800	32.87	32.81	16.40	16.32	6.318	6.288	3.06	3.03	1.46	1.45
.3056	.3442	.3825	33.10	33.04	16.52	16.44	6.366	6.337	3.08	3.05	1.47	1.47
.3076	.3465	.3850	33.34	33.28	16.64	16.56	6.414	6.386	3.10	3.07	1.48	1.48
.3096	.3487	.3875	33.58	33.52	16.76	16.68	6.462	6.434	3.12	3.09	1.49	1.49
.3116	.3510	.3900	33.82	33.76	16.88	16.80	6.510	6.482	3.15	3.12	1.51	1.50
.3136	.3532	.3925	34.06	34.00	17.00	16.92	6.558	6.531	3.17	3.14	1.52	1.51
.3156	.3555	.3950	34.30	34.24	17.12	17.04	6.608	6.580	3.19	3.16	1.53	1.52
.3176	.3577	.3975	34.54	34.48	17.24	17.16	6.654	6.629	3.21	3.18	1.54	1.53
.3196	.3600	.4000	34.78	34.72	17.36	17.28	6.703	6.678	3.24	3.21	1.55	1.54
.3216	.3622	.4025	35.02	34.96	17.48	17.40	6.751	6.727	3.26	3.23	1.56	1.55
.3236	.3645	.4050	35.26	35.20	17.60	17.52	6.799	6.776	3.28	3.26	1.57	1.56
.3256	.3667	.4075	35.50	35.44	17.72	17.64	6.848	6.825	3.30	3.27	1.58	1.57
.3275	.3690	.4100	35.75	35.68	17.84	17.76	6.897	6.875	3.33	3.30	1.60	1.59
.3295	.3712	.4125	35.99	35.92	17.96	17.88	6.945	6.924	3.35	3.32	1.61	1.60
.3315	.3735	.4150	36.24	36.16	18.08	18.00	6.993	6.973	3.37	3.34	1.62	1.61
.3335	.3757	.4175	36.48	36.40	18.20	18.12	7.042	7.023	3.39	3.36	1.63	1.62
.3355	.3780	.4200	36.73	36.65	18.33	18.25	7.091	7.073	3.42	3.39	1.64	1.63
.3375	.3802	.4225	36.97	36.89	18.45	18.37	7.139	7.122	3.44	3.41	1.65	1.64
.3395	.3825	.4250	37.22	37.13	18.57	18.49	7.188	7.172	3.46	3.43	1.66	1.65
.3415	.3847	.4275	37.47	37.37	18.69	18.61	7.237	7.222	3.48	3.45	1.67	1.66
.3435	.3870	.4300	37.72	37.62	18.82	18.74	7.286	7.272	3.51	3.48	1.69	1.68
.3455	.3892	.4325	37.96	37.86	18.94	18.86	7.334	7.321	3.53	3.50	1.70	1.69
.3475	.3915	.4350	38.21	38.10	19.06	18.99	7.383	7.371	3.55	3.52	1.71	1.70
.3495	.3937	.4375	38.46	38.44	19.19	19.12	7.432	7.421	3.58	3.55	1.72	1.71

363. TABLE FOR THE DETERMINATION OF COEFFICIENTS OF PURITY.—(G. KOTTMANN.)

Per Cent Sucrose.	Per Cent of Non-Sucrose = Degree Brix minus Per Cent Sucrose.									Per Cent Sucrose.
	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	
8.0	88.9	87.9	87.0	86.0	85.1	84.2	83.3	82.5	81.6	8.0
8.2	89.1	88.2	87.2	86.3	85.4	84.5	63.7	82.8	82.0	8.2
8.4	89.4	88.4	87.5	86.6	85.7	84.8	84.0	83.2	82.3	8.4
8.6	89.6	88.7	87.8	86.9	86.0	85.1	84.3	83.5	82.7	8.6
8.8	89.8	88.9	88.0	87.1	86.3	85.4	84.6	83.8	83.0	8.8
9.0	90.0	89.1	88.2	87.4	86.5	85.7	84.9	84.1	83.3	9.0
9.2	90.2	89.3	88.5	87.6	86.8	86.0	85.2	84.4	83.6	9.2
9.4	90.4	89.5	88.7	87.8	87.0	86.2	85.5	84.7	83.9	9.4
9.6	90.6	89.7	88.9	88.1	87.3	86.5	85.7	85.0	84.2	9 6
9.8	90.7	89.9	89.1	88.3	87.5	86.7	86.0	85.2	84.5	9.8
10.0	90.9	90.1	89.3	88.5	87.7	87.0	86.2	85.5	84.7	10.0
10.2	91.1	90.3	89.5	88.7	87.9	87.2	86.4	85.7	85.0	10 2
10.4	91.2	90.4	89.7	88.9	88.1	87.4	86.7	86.0	85.2	10.4
10.6	91.4	90.6	89.8	89.1	88.3	87.6	86.9	86.2	85.5	10.6
10.8	91.5	90.8	90.0	89.3	88.5	87.8	87.1	86.4	85.7	10.8
11.0	91.7	90.9	90.2	89.4	88.7	88.0	87.3	86.6	85.9	11.0
11.2	91.8	91.1	90.3	89.6	88.9	88.2	87.5	86.8	86.2	11.2
11.4	91.9	91.2	90.5	89.8	89.1	88.4	87.7	87.0	86.4	11.4
11.6	92.1	91.3	90.6	89 9	89 2	88.5	87.9	87.2	86.6	11.6
11.8	92.2	91.5	90.8	90.1	89.4	88.7	88.1	87.4	86.8	11.8
12.0	92.3	91.6	90.9	90.2	89.6	88.9	88.2	87.6	87.0	12.0
12.2	92.4	91.7	91.0	90 4	89.7	89.1	88.4	87.8	87.1	12.2
12.4	92.5	91.9	91.2	90.5	89.9	89.2	88.6	87.9	87.3	12.4
12.6	92.6	92.0	91.3	90 6	90.0	89.4	88.7	88.1	87.5	12.6
12.8	92.8	92.1	91.4	90.8	90.1	89.5	88.9	88.3	87.7	12.8
13.0	92.9	92.2	91.5	90.9	90.3	89.7	89.0	88.4	87.8	13.0
13.2	93.0	92.3	91.7	91.0	90.4	89.8	89 2	88.6	88.0	13.2
13.4	93.1	92.4	91.8	91.2	90.5	89 9	89.3	88 7	88.2	13.4
13.6	93.2	92.5	91.9	91 3	90.7	90.1	89.5	88.9	88.3	13.6
13.8	93.2	92.6	92.0	91.4	90 8	90.2	89.6	89.0	88.5	13.8
14.0	93.3	92.7	92.1	91.5	90.9	90.3	89.7	89 2	88.6	14.0
14.2	93.4	92.8	92.2	91.6	91.0	90.4	89.9	89.3	88.8	14.2
14.4	93.5	92.9	92.3	91.7	91.1	90.6	90.0	89.4	88 9	14.4
14.6	93.6	93.0	92.4	91.8	91.3	90.7	90.1	89.6	89.0	14.6
14.8	93.7	93.1	92.5	91.9	91.4	90.8	90.2	89.7	89.2	14.8
15.0	93.7	93.2	92.6	92 0	91.5	90.9	90.4	89.8	89.3	15.0
15.2	93.8	93.3	92.7	92.1	91.6	91.0	90.5	89.9	89.4	15.2
15.4	93.9	93.3	92.8	92.2	91.7	91.1	90.6	90.1	89.5	15.4
15.6	94.0	93.4	92.8	92.3	91.8	91.2	90.7	90.2	89.7	15.6
15.8	94.1	93.5	92.9	92.4	91.9	91.3	90.8	90.3	89.8	15.8
16.0	94.1	93.6	93.0	92.5	92.0	91.4	90.9	90.4	89 9	16.0
16.2	94.2	93.7	93.1	92.6	92.0	91.5	91.0	90.5	90.0	16.2
16.4	94.3	93.7	93.2	92.6	92.1	91.6	91.1	90.6	90.1	16.4
16 6	94.3	93.8	93.3	92.7	92.2	91.7	91.2	90.7	90.2	16.6
16.8	94.4	93.9	93.3	92.8	92.3	91.8	91.3	90.8	90.3	16.8
17.0	94.4	93.9	93.4	92.9	92.4	91.9	91.4	90.9	90.4	17.0

TABLE FOR THE DETERMINATION OF COEFFICIENTS OF
PURITY.—*Continued.*

Per Cent Sucrose	Per Cent of Non-Sucrose = Degree Brix minus Per Cent Sucrose									Per Cent Sucrose
	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	
8.0	80.8	80.0	79.2	78.4	77.7	76.9	76.2	75.5	74.8	8.0
8.2	81.2	80.4	79.6	78.8	78.1	77.4	76.6	75.9	75.2	8.2
8.4	81.5	80.8	80.0	79.2	78.5	77.8	77.1	76.4	75.7	8.4
8.6	81.9	81.1	80.4	79.6	78.9	78.2	77.5	76.8	76.1	8.6
8.8	82.2	81.5	80.7	80.0	79.3	78.6	77.9	77.2	76.5	8.8
9.0	82.6	81.8	81.1	80.4	79.6	78.9	78.3	77.6	76.9	9.0
9.2	82.9	82.1	81.4	80.7	80.0	79.3	78.6	77.9	77.3	9.2
9.4	83.2	82.5	81.7	81.0	80.3	79.7	79.0	78.3	77.7	9.4
9.6	83.5	82.8	82.1	81.4	80.7	80.0	79.3	78.7	78.0	9.6
9.8	83.8	83.1	82.4	81.7	81.0	80.3	79.7	79.0	78.4	9.8
10.0	84.0	83.3	82.6	82.0	81.3	80.6	80.0	79.4	78.7	10.0
10.2	84.3	83.6	82.9	82.3	81.6	81.0	80.3	79.7	79.1	10.2
10.4	84.6	83.9	83.2	82.5	81.9	81.2	80.6	80.0	79.4	10.4
10.6	84.8	84.1	83.5	82.8	82.2	81.5	80.9	80.3	79.7	10.6
10.8	85.0	84.4	83.7	83.1	82.4	81.8	81.2	80.6	80.0	10.8
11.0	85.3	84.6	84.0	83.3	82.7	82.1	81.5	80.9	80.3	11.0
11.2	85.5	84.8	84.2	83.6	83.0	82.4	81.8	81.2	80.6	11.2
11.4	85.7	85.1	84.4	83.8	83.2	82.6	82.0	81.4	80.9	11.4
11.6	85.9	85.3	84.7	84.1	83.5	82.9	82.3	81.7	81.1	11.6
11.8	86.1	85.5	84.9	84.3	83.7	83.1	82.5	81.9	81.4	11.8
12.0	86.3	85.7	85.1	84.5	83.9	83.3	82.8	82.2	81.6	12.0
12.2	86.5	85.9	85.3	84.7	84.1	83.6	83.0	82.4	81.9	12.2
12.4	86.7	86.1	85.5	84.9	84.4	83.8	83.2	82.7	82.1	12.4
12.6	86.9	86.3	85.7	85.1	84.6	84.0	83.4	82.9	82.3	12.6
12.8	87.1	86.5	85.9	85.3	84.8	84.2	83.7	83.1	82.6	12.8
13.0	87.2	86.7	86.1	85.5	85.0	84.4	83.9	83.3	82.8	13.0
13.2	87.4	86.8	86.3	85.7	85.2	84.6	84.1	83.5	83.0	13.2
13.4	87.6	87.0	86.5	85.9	85.4	84.8	84.3	83.7	83.2	13.4
13.6	87.7	87.2	86.6	86.1	85.5	85.0	84.5	83.9	83.4	13.6
13.8	87.9	87.3	86.8	86.3	85.7	85.2	84.7	84.1	83.6	13.8
14.0	88.1	87.5	87.0	86.4	85.9	85.4	84.8	84.3	83.8	14.0
14.2	88.2	87.7	87.1	86.6	86.1	85.5	85.0	84.5	84.0	14.2
14.4	88.3	87.8	87.3	86.7	86.2	85.7	85.2	84.7	84.2	14.4
14.6	88.5	88.0	87.4	86.9	86.4	85.9	85.4	84.9	84.4	14.6
14.8	88.6	88.1	87.6	87.1	86.5	86.0	85.5	85.1	84.6	14.8
15.0	88.8	88.2	87.7	87.2	86.7	86.2	85.7	85.2	84.7	15.0
15.2	88.9	88.4	87.9	87.4	86.9	86.4	85.9	85.4	84.9	15.2
15.4	89.0	88.5	88.0	87.5	87.0	86.5	86.0	85.6	85.1	15.4
15.6	89.1	88.6	88.1	87.6	87.2	86.7	86.2	85.7	85.2	15.6
15.8	89.3	88.8	88.3	87.8	87.3	86.8	86.3	85.9	85.4	15.8
16.0	89.4	88.9	88.4	87.9	87.4	87.0	86.5	86.0	85.6	16.0
16.2	89.5	89.0	88.5	88.0	87.6	87.1	86.6	86.2	85.7	16.2
16.4	89.6	89.1	88.6	88.2	87.7	87.2	86.8	86.3	85.9	16.4
16.6	89.7	89.2	88.8	88.3	87.8	87.4	86.9	86.5	86.0	16.6
16.8	89.8	89.4	88.9	88.4	88.0	87.5	87.0	86.6	86.2	16.8
17.0	89.9	89.5	89.0	88.5	88.1	87.6	87.2	86.7	86.3	17.0

TABLE FOR THE DETERMINATION OF COEFFICIENTS OF PURITY.—Continued.

Per Cent Sucrose	Per Cent of Non-Sucrose = Degree Brix minus Per Cent Sucrose.									Per Cent Sucrose
	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	
8.0	74.1	73.4	72.7	72.1	71.4	70.8	70.2	69.6	69.0	8.0
8.2	74.5	73.9	73.2	72.6	71.9	71.3	70.7	70.1	69.5	8.2
8.4	75.0	74.3	73.7	73.0	72.4	71.8	71.2	70.6	70.0	8.4
8.6	75.4	74.8	74.1	73.5	72.9	72.3	71.7	71.1	70.5	8.6
8.8	75.9	75.2	74.6	73.9	73.3	72.7	72.1	71.5	71.0	8.8
9.0	76.3	75.6	75.0	74.4	73.8	73.2	72.6	72.0	71.4	9.0
9.2	76.7	76.0	75.4	74.8	74.2	73.6	73.0	72.4	71.9	9.2
9.4	77.0	76.4	75.8	75.2	74.6	74.0	73.4	72.9	72.3	9.4
9.6	77.4	76.8	76.2	75.6	75.0	74.4	73.8	73.3	72.7	9.6
9.8	77.8	77.2	76.6	76.0	75.4	74.8	74.2	73.7	73.1	9.8
10.0	78.1	77.5	76.9	76.3	75.8	75.2	74.6	74.1	73.5	10.0
10.2	78.5	77.9	77.3	76.7	76.1	75.6	75.0	74.5	73.9	10.2
10.4	78.8	78.2	77.6	77.0	76.5	75.9	75.4	74.8	74.3	10.4
10.6	79.1	78.5	77.9	77.4	76.8	76.3	75.7	75.2	74.6	10.6
10.8	79.4	78.8	78.3	77.7	77.1	76.6	76.1	75.5	75.0	10.8
11.0	79.7	79.1	78.6	78.0	77.5	76.9	76.4	75.9	75.3	11.0
11.2	80.0	79.4	78.9	78.3	77.8	77.2	76.7	76.2	75.7	11.2
11.4	80.3	79.7	79.2	78.6	78.1	77.6	77.0	76.5	76.0	11.4
11.6	80.6	80.0	79.4	78.9	78.4	77.9	77.3	76.8	76.3	11.6
11.8	80.8	80.3	79.7	79.2	78.7	78.1	77.6	77.1	76.6	11.8
12.0	81.1	80.5	80.0	79.5	78.9	78.4	77.9	77.4	76.9	12.0
12.2	81.3	80.8	80.3	79.7	79.2	78.7	78.2	77.7	77.2	12.2
12.4	81.6	81.0	80.5	80.0	79.5	79.0	78.5	78.0	77.5	12.4
12.6	81.8	81.3	80.8	80.3	79.7	79.2	78.8	78.3	77.8	12.6
12.8	82.1	81.5	81.0	80.5	80.0	79.5	79.0	78.5	78.0	12.8
13.0	82.3	81.8	81.2	80.7	80.2	79.8	79.3	78.8	78.3	13.0
13.2	82.5	82.0	81.5	81.0	80.5	80.0	79.5	79.0	78.6	13.2
13.4	82.7	82.2	81.7	81.2	80.7	80.2	79.8	79.3	78.8	13.4
13.6	82.9	82.4	81.9	81.4	81.0	80.5	80.0	79.5	79.1	13.6
13.8	83.1	82.6	82.1	81.7	81.2	80.7	80.2	79.8	79.3	13.8
14.0	83.3	82.8	82.3	81.9	81.4	80.9	80.5	80.0	79.5	14.0
14.2	83.5	83.0	82.5	82.1	81.6	81.1	80.7	80.2	79.8	14.2
14.4	83.7	83.2	82.7	82.3	81.8	81.4	80.9	80.4	80.0	14.4
14.6	83.9	83.4	82.9	82.5	82.0	81.6	81.1	80.7	80.2	14.6
14.8	84.1	83.6	83.1	82.7	82.2	81.8	81.3	80.9	80.4	14.8
15.0	84.3	83.8	83.3	82.9	82.4	82.0	81.5	81.1	80.6	15.0
15.2	84.4	84.0	83.5	83.1	82.6	82.2	81.7	81.3	80.8	15.2
15.4	84.6	84.2	83.7	83.2	82.8	82.4	81.9	81.5	81.0	15.4
15.6	84.8	84.3	83.9	83.4	83.0	82.5	82.1	81.7	81.2	15.6
15.8	84.9	84.5	84.0	83.6	83.2	82.7	82.3	81.9	81.4	15.8
16.0	85.1	84.7	84.2	83.8	83.3	82.9	82.5	82.0	81.6	16.0
16.2	85.3	84.8	84.4	83.9	83.5	83.1	82.7	82.2	81.8	16.2
16.4	85.4	84.9	84.5	84.1	83.7	83.2	82.8	82.4	82.0	16.4
16.6	85.6	85.1	84.7	84.3	83.8	83.4	83.0	82.6	82.2	16.6
16.8	85.7	85.3	84.8	84.4	84.0	83.6	83.2	82.8	82.4	16.8
17.0	85.9	85.4	85.0	84.6	84.2	83.7	83.3	82.9	82.5	17.0

TABLE FOR THE DETERMINATION OF COEFFICIENTS OF PURITY.—*Continued.*

Per Cent Sucrose	Per Cent of Non-Sucrose = Degree Brix minus Per Cent Sucrose.									Per Cent Sucrose
	3.7	3 8	3.9	4.0	4.1	4.2	4.3	4.4	4 5	
8.0	68.4	67.8	67 2	66.7	66.1	65.6	65.0	64.5	64.0	8.0
8.2	68.9	68.3	67.8	67.2	66.7	66.1	65.6	65.1	64.6	8.2
8.4	69 4	68.8	68.3	67.7	67.2	66.7	66.1	65.6	65.1	8.4
8.6	69.9	69.3	68.8	68.3	67.7	67.2	66.7	66.2	65.6	8.6
8.8	70.4	69.8	69.3	68.8	68.2	67.7	67.2	66.7	66.2	8.8
9.0	70.9	70.3	69.8	69 2	68.7	68.2	67 7	67.2	66.7	9.0
9.2	71.3	70.8	70.2	69.7	69.2	68.7	68.1	67.6	67.2	9.2
9.4	71.8	71.2	70.7	70.1	69.6	69.1	68.6	68.1	67.6	9.4
9.6	72.2	71.6	71.1	70.6	70.1	69.6	69.1	68.6	68.1	9.6
9.8	72.6	72.1	71.5	71.0	70.5	70.0	69.5	69.0	68.5	9.8
10.0	73.0	72.5	71.9	71.4	70.9	70.4	69.9	69.4	69.0	10.0
10.2	73.4	72.9	72.3	71.8	71.3	70.8	70.3	69.9	69.4	10.2
10.4	73.8	73.2	72.7	72.2	71.7	71.2	70.7	70.3	69.8	10.4
10.6	74.1	73.6	73.1	72.6	72.1	71.6	71.1	70.7	70.2	10.6
10.8	74.5	74.0	73.5	73.0	72.5	72.0	71.5	71.1	70.6	10.8
11.0	74.8	74.3	73.8	73.3	72.8	72.4	71.9	71.4	71.0	11.0
11.2	75.2	74.7	74.2	73.7	73.2	72.7	72.3	71.8	71.3	11.2
11.4	75.5	75.0	74.5	74.0	73.5	73.1	72.6	72.2	71.7	11.4
11.6	75.8	75.3	74.8	74.4	73.9	73.4	76.0	72.5	72.0	11.6
11.8	76.1	75.6	75.2	74.7	74.2	73.8	73.3	72.8	72.4	11.8
12.0	76.4	75.9	75.5	75.0	74.5	74.1	73.6	73.2	72.7	12.0
12.2	76.7	76.2	75.8	75.3	74.8	74.4	73.9	73.5	73.1	12.2
12.4	77.0	76.5	76.1	75.6	75.2	74.7	74.3	73.8	73.4	12.4
12.6	77.3	76.8	76.4	75.9	75.4	75.0	74.6	74.1	73.7	12.6
12.8	77.6	77.1	76.6	76.2	75.7	75.3	74.9	74.4	74.0	12.8
13.0	77.8	77.4	76.9	76.5	76.0	75.6	75.1	74.7	74.3	13.0
13.2	78.1	77.6	77.2	76.7	76.3	75.9	75.4	75.0	74.6	13.2
13.4	78.4	77.9	77.5	77.0	76.6	76.1	75.7	75.3	74.9	13.4
13.6	78.6	78.2	77.7	77.3	76.8	76.4	76.0	75.6	75.1	13.6
13.8	78.9	78.4	78.0	77.5	77.1	76.7	76.2	75.8	75.4	13.8
14.0	79.1	78.7	78.2	77.8	77.3	76.9	76.5	76.1	75.7	14.0
14.2	79 3	78.9	78.5	78.0	77.6	77.2	76 3	75.9		14.2
14.4	79.6	79.1	78.7	78.3	77.8	77.4	77.0	76.6	76.2	14.4
14.6	79.8	79.3	78.9	78.5	78.1	77.6	77.2	76.8	76.4	14.6
14.8	80.0	79.6	79.1	78.7	78.3	77.9	77.5	77.1	76.7	14.8
15.0	80.2	79.8	79.4	78.9	78.5	78.1	77.7	77.3	76.9	15.0
15.2	80.4	80.0	79.6	79.2	78.8	78.4	77.9	77.6	77.2	15.2
15 4	80.6	80.2	79.8	79.4	79.0	78.6	78.2	77.8	77.4	15.4
15.6	80.8	80.4	80 0	79.6	79.2	78.8	78.4	78.0	77.6	15.6
15.8	81.0	80.6	80.2	79.8	79.4	79.0	78.6	78.2	77.8	15.8
16.0	81.2	80.8	80.4	80.0	79.6	79.2	78.8	78.4	78.0	16.0
16.2	81.4	81.0	80.6	80.2	79.8	79.4	79.0	78.6	78.3	16.2
16.4	81.6	81.2	80.8	80.4	80.0	79.6	79.2	78.8	78.5	16.4
16.6	81.8	81.4	81.0	80.6	80.2	79.8	79.4	79.0	78.7	16.6
16.8	82.0	81.6	81.2	80.8	80.4	80.0	79.6	79.2	78.9	16.8
17.0	82.1	81.7	81.3	81.0	80.6	80.2	79.8	79.4	79.1	17.0

334. HORNE'S TABLE FOR THE CALCULATION OF COEFFICIENTS OF PURITY IN THE VACUUM-PAN AND CRYSTALLIZER CONTROL.

Dr. W. D. Horne's[1] method of dry defecation in optical sugar analysis affords a rapid means of controlling the pans and crystallizers. The methods of obtaining the samples of massecuite and molasses are described in 199.

The sample of massecuite or molasses should be dissolved in water and the solution so diluted that the Brix hydrometer will sink in it nearly or quite to the 15° mark. After a little practice the chemist will find that he can prepare such solutions with ease. To an unmeasured portion of the solution, in a small glass cylinder, add sufficient powdered anhydrous lead subacetate and a little coarse dry sand to defecate the solution. Cover the cylinder and shake the solution thoroughly with the lead salt and sand, filter, and polarize the filtrate. In Dr. Horne's table on the following pages, opposite the corrected degree Brix and under the polariscope reading, is the coefficient of purity of the solution. Example: Brix 15.4°; polarization 24.4. Under the latter number and opposite 15.4° Brix is the coefficient of purity, 38.9.

It should be noted that this method, using the dry subacetate, gives somewhat lower coefficients of purity than the ordinary method, using the solution of the lead salt. This is unobjectionable, provided the same method is used in all comparative tests.[2]

Dr. Horne used Casamajor's formula, as follows, in calculating this table:

$$\text{Factor} = \frac{26.048}{\text{Degree Brix} \times \text{Specific gravity}};$$

Coefficient of purity = Factor × Polariscope reading.

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[1] Journal of American Chemical Society, **26**, No. 2, 186.
[2] *See* also page 179.

365. HORNE'S TABLE OF COEFFICIENTS OF PURITY.

Pol.= / °Brix	16.0	16.2	16.4	16.6	16.8	17.0	17.2	17.4	17.6	17.8	18.0	18.2	18.4	18.6	18.8	19.0
15.0	26.2	26.5	26.8	27.2	27.5	27.8	28.1	28.5	28.8	29.1	29.4	29.8	30.1	30.4	30.8	31.1
.1	26.0	26.3	26.7	27.0	27.3	27.6	28.0	28.3	28.6	28.9	29.3	29.6	29.9	30.2	30.6	30.9
.2	25.8	26.1	26.3	26.8	27.1	27.4	27.7	28.1	28.4	28.7	29.0	29.2	29.5	30.0	30.3	30.6
.3	25.6	25.8	26.1	26.4	26.7	27.0	27.4	27.7	28.0	28.3	28.8	29.0	29.3	29.8	30.1	30.4
.4	25.3	25.6	25.9	26.2	26.5	27.0	27.2	27.5	27.8	28.1	28.4	28.8	29.1	29.6	29.7	30.2
.5	25.1	25.4	25.7	26.0	26.4	26.7	27.0	27.1	27.6	27.8	28.2	28.6	28.9	29.4	29.5	30.0
.6	24.9	25.3	25.6	26.0	26.2	26.5	26.8	27.1	27.4	27.6	28.1	28.4	28.7	29.0	29.3	30.8
.7	24.8	25.1	25.4	25.9	26.0	26.3	26.6	26.9	27.2	27.6	27.9	28.2	28.5	29.0	29.1	29.6
.8	24.6	24.9	25.2	25.7	25.8	26.1	26.5	26.8	27.1	27.4	27.7	28.0	28.3	28.6	28.9	29.4
.9	24.6	24.9	25.2	25.5	25.8	26.1	26.5	26.8	27.1	27.4	27.7	28.0	28.3	28.5	28.9	29.2

Pol.= / °Brix	19.2	19.4	19.6	19.8	20.0	20.2	20.4	20.6	20.8	21.0	21.2	21.4	21.6	21.8	22.0	22.2
15.0	31.4	31.7	32.1	32.4	32.7	33.0	33.4	33.7	34.0	34.4	34.7	35.0	35.3	35.7	36.0	36.3
.1	31.2	31.5	31.9	32.2	32.5	32.8	33.2	33.5	33.8	34.1	34.5	34.8	35.1	35.4	35.8	36.1
.2	31.0	31.3	31.6	32.0	32.3	32.6	32.9	33.3	33.6	33.9	34.2	34.5	35.0	35.2	35.5	35.8
.3	30.8	31.1	31.4	31.7	32.0	32.4	32.7	33.0	33.3	33.4	34.0	34.3	34.6	34.9	35.2	35.6
.4	30.5	30.9	31.2	31.5	31.8	32.1	32.5	32.8	33.1	33.4	33.5	34.0	34.4	34.7	35.0	35.1
.5	30.3	30.7	31.0	31.3	31.6	31.9	32.2	32.5	32.9	33.2	33.5	33.6	34.1	34.4	34.5	35.1
.6	30.1	30.4	30.9	31.1	31.4	31.7	32.0	32.2	32.7	33.0	33.1	33.6	33.4	34.2	34.5	34.8
.7	29.9	30.2	30.7	30.9	31.2	31.5	31.8	32.1	32.4	32.7	33.1	33.3	33.7	33.4	34.3	34.1
.8	29.7	30.0	30.4	30.8	31.0	31.3	31.6	31.9	32.2	32.5	32.8	33.1	33.2	33.7	34.0	34.4
.9	29.5	29.8	30.5	30.8	31.1	31.4	31.7	31.9	32.3	32.6	32.3	32.6	33.2	33.5	33.8	34.1

Pol.= / °Brix	22.4	22.6	22.8	23.0	23.2	23.4	23.6	23.8	24.0	24.2	24.4	24.6	24.8	25.0	25.2	25.4
15.0	36.6	37.0	37.3	37.6	38.0	38.3	38.6	38.9	39.3	39.6	39.9	40.3	40.6	40.9	41.2	41.6
.1	36.4	36.5	37.1	37.4	37.7	38.0	38.4	38.7	39.0	39.3	39.7	40.0	40.6	40.8	41.0	41.3
.2	36.1	36.2	37.1	37.2	37.4	37.7	38.1	38.4	38.7	39.0	39.4	39.7	40.3	40.4	40.6	41.2
.3	35.9	36.2	36.5	37.2	37.3	37.5	37.9	38.1	38.4	38.5	38.8	39.4	39.7	41.0	40.4	40.7
.4	35.6	36.0	36.3	36.3	37.5	37.3	37.6	37.9	38.2	38.5	38.8	39.1	39.5	39.1	41.0	40.4
.5	35.4	36.7	36.1	36.1	37.0	37.2	37.4	37.3	37.7	38.0	38.3	38.6	38.9	39.2	41.8	40.4
.6	35.1	35.5	35.8	36.1	37.0	36.5	37.3	37.1	37.4	37.7	38.0	38.1	38.7	39.0	39.5	39.9
.7	35.1	35.2	35.5	36.0	36.8	36.4	37.0	36.8	37.4	37.5	38.0	38.1	38.4	39.0	39.0	40.1
.8	34.7	35.0	35.3	35.9	36.9	36.2	36.5	36.6	37.2	37.5	37.8	38.1	38.1	38.7	39.0	39.9
.9	34.5	34.8	35.1	35.7	36.3	36.0	36.3	36.6	37.5	37.2	37.5	37.8	38.1	38.5	38.8	39.1

HORNE'S TABLE—(Continued).

Pol. = Brix.	25.6	25.8	26.0	26.2	26.4	26.6	26.8	27.0	27.2	27.4	27.6	27.8	28.0	28.2	28.4	28.6
15.0	41.9	42.2	42.5	42.9	43.2	43.5	43.8	44.2	44.5	44.8	45.2	45.5	45.8	46.1	46.5	46.8
.1	41.6	41.9	42.3	42.6	42.9	43.2	43.6	43.9	44.2	44.5	44.9	45.2	45.5	45.8	46.2	46.5
.2	41.3	41.6	41.9	42.3	42.6	42.9	43.2	43.6	43.9	44.2	44.5	44.8	45.2	45.5	45.8	46.1
.3	41.1	41.0	41.7	42.0	42.0	42.3	42.6	43.0	43.3	43.6	43.9	44.2	44.6	44.9	45.2	45.5
.4	40.7	40.8	41.4	41.7	41.7	42.0	42.3	42.7	43.0	43.3	43.6	44.0	44.2	44.6	44.9	45.2
.5	40.4	40.5	41.1	41.4	41.7	41.7	42.0	42.4	42.7	43.0	43.3	43.6	44.0	44.2	44.9	44.9
.6	40.2	40.2	40.8	41.1	41.2	41.5	41.7	42.1	42.4	42.7	43.0	43.3	43.7	43.9	44.4	44.6
.7	40.0	40.0	40.5	40.9	40.9	41.2	41.5	41.8	42.1	42.4	42.7	43.0	43.7	43.7	44.0	44.6
.8	39.6	39.9	40.2	40.6	40.9	41.2	41.5	41.8	41.8	42.1	42.4	42.8	43.3	43.6	44.0	44.2
.9	39.4	39.7	40.0	40.3	40.6	40.9	41.2	41.5	41.8	42.1	42.4	42.8	43.1	43.4	43.7	44.0

Pol. =	28.8	29.0	29.2	29.4	29.6	29.8	30.0	30.2	30.4	30.6	30.8	31.0	31.2	31.4	31.6	31.8
15.0	47.1	47.4	47.8	48.1	48.4	48.8	49.1	49.4	49.7	50.1	50.4	50.7	51.0	51.4	51.7	52.0
.1	46.8	47.1	47.5	47.8	48.1	48.4	48.8	49.1	49.4	49.7	50.1	50.4	50.7	51.0	51.4	51.7
.2	46.5	46.8	47.1	47.7	47.7	48.1	48.4	48.7	49.0	49.4	49.7	50.0	50.3	50.6	51.0	51.3
.3	46.1	46.5	46.8	47.1	47.4	47.7	48.1	48.4	48.7	49.0	49.3	49.7	50.0	50.3	50.6	50.9
.4	45.8	46.1	46.5	46.8	47.1	47.4	47.7	48.1	48.4	48.7	49.0	49.3	50.0	50.0	50.3	50.6
.5	45.5	45.8	46.1	46.5	46.8	47.1	47.4	47.7	48.0	48.4	48.7	49.0	49.3	49.6	49.9	50.2
.6	45.2	45.5	45.8	46.1	46.4	46.8	47.1	47.4	47.7	48.0	48.3	48.6	48.8	49.3	49.3	49.6
.7	45.2	45.2	45.5	45.8	46.1	46.5	46.8	47.1	47.4	47.7	48.0	48.3	48.6	48.6	48.8	49.2
.8	44.4	44.8	45.2	45.5	45.8	46.1	46.4	46.7	47.0	47.4	47.7	47.9	48.3	48.6	48.9	49.2
.9	44.3	44.6	44.9	45.2	45.5	45.8	46.1	46.4	46.8	47.1	47.4	47.7	48.0	48.3	48.6	48.9

Pol. =	32.0	32.2	32.4	32.6	32.8	33.0	33.2	33.4	33.6	33.8	34.0	34.2	34.4	34.6	34.8	35.0
15.0	52.4	52.7	53.0	53.3	53.7	54.0	54.3	54.6	55.0	55.3	55.6	56.0	56.3	56.6	56.9	57.3
.1	52.0	52.3	52.7	53.0	53.3	53.6	54.0	54.3	54.6	54.9	55.3	55.6	55.9	56.2	56.6	56.9
.2	51.9	52.0	52.4	52.8	52.9	53.2	53.6	53.9	54.2	54.5	54.8	55.1	55.4	55.8	56.1	56.5
.3	51.3	51.6	51.9	52.2	52.5	52.9	53.2	53.5	53.8	54.1	54.5	54.8	55.1	55.4	55.7	56.1
.4	50.6	51.2	51.2	51.9	52.2	52.5	52.8	53.1	53.4	53.8	54.1	54.4	54.7	55.0	55.5	55.7
.5	50.6	50.9	51.2	51.5	51.8	52.1	52.5	52.4	53.1	53.4	53.7	54.0	54.4	54.7	55.0	54.9
.6	50.2	50.5	50.8	51.1	51.4	51.8	52.1	52.4	52.7	53.0	53.3	53.6	54.0	54.3	54.6	54.9
.7	49.9	50.5	50.8	51.1	51.4	51.4	51.8	52.1	52.4	52.7	53.0	53.9	53.7	54.0	54.3	54.6
.8	49.9	49.8	50.2	50.5	50.8	51.1	51.4	51.7	52.0	52.3	52.6	52.9	53.8	53.6	53.9	54.2
.9	49.5	49.5	49.8	50.1	50.4	50.8	51.2	51.5	51.8	52.1	52.3	52.6	52.9	53.2	53.5	53.8

HORNE'S TABLE—(Continued).

Pol.= Brix	35.2	35.4	35.6	35.8	36.0	36.2	36.4	36.6	36.8	37.0	37.2	37.4	37.6	37.8	38.0	38.2
15.0	57.6	57.9	58.2	58.6	58.9	59.2	59.6	59.9	60.2	60.5	60.9	61.2	61.5	61.8	62.2	62.5
.1	57.2	57.5	57.9	58.2	58.5	58.8	59.2	59.5	59.8	60.1	60.5	60.8	61.1	61.4	61.8	62.1
.2	56.8	57.1	57.4	57.7	58.1	58.4	58.7	59.0	59.4	59.7	60.0	60.3	60.6	61.0	61.3	61.6
.3	56.6	56.7	57.0	57.4	57.7	58.0	58.3	58.8	59.0	59.3	59.8	59.9	60.8	60.6	60.9	61.2
.4	56.0	56.3	56.6	57.0	57.3	57.6	57.9	58.2	58.6	58.9	59.2	59.5	59.8	60.1	60.5	60.8
.5	55.6	55.9	56.2	56.6	56.9	57.2	57.5	57.8	58.1	58.5	58.8	59.1	59.4	59.7	60.0	60.4
.6	55.3	55.5	55.8	56.2	56.5	56.8	57.1	57.4	57.7	58.1	58.4	58.7	59.0	59.3	59.6	59.9
.7	54.9	55.2	55.5	55.8	56.1	56.4	56.7	57.1	57.4	57.7	58.0	58.3	58.6	58.9	59.2	59.6
.8	54.5	54.8	55.1	55.4	55.7	56.0	56.3	56.7	57.0	57.3	57.6	57.9	58.2	58.5	58.8	59.1
.9	54.1	54.4	54.8	55.1	55.4	55.7	56.0	56.3	56.6	56.9	57.2	57.5	57.8	58.1	58.4	58.8

Pol.= Brix	38.4	38.6	38.8	39.0	39.2	39.4	39.6	39.8	40.0	40.2	40.4	40.6	40.8	41.0	41.2	41.4
15.0	62.8	63.1	63.5	63.8	64.1	64.5	64.8	65.1	65.4	65.8	66.1	66.4	66.7	67.1	67.4	67.7
.1	62.4	62.7	63.1	63.4	63.7	64.0	64.4	64.7	65.0	65.3	65.7	66.0	66.3	66.6	67.0	67.3
.2	61.9	62.3	62.7	62.9	63.2	63.6	63.9	64.2	64.5	64.9	65.2	65.5	65.8	66.1	66.5	66.8
.3	61.5	61.8	62.2	62.5	62.8	63.1	63.5	63.8	64.1	64.4	64.7	65.0	65.4	65.7	66.0	66.3
.4	61.1	61.4	61.8	62.0	62.4	62.7	63.0	63.3	63.6	64.0	64.3	64.6	64.9	65.2	65.5	65.9
.5	60.7	61.0	61.3	61.6	61.9	62.3	62.6	62.9	63.2	63.5	63.8	64.1	64.5	64.8	65.1	65.4
.6	60.2	60.6	60.9	61.2	61.5	61.8	62.1	62.4	62.8	63.1	63.4	63.7	64.0	64.3	64.6	65.0
.7	59.9	60.2	60.5	60.8	61.1	61.4	61.7	62.0	62.4	62.7	63.0	63.3	63.6	63.9	64.2	64.5
.8	59.4	59.8	60.1	60.4	60.7	61.0	61.3	61.6	61.9	62.2	62.5	62.8	63.2	63.5	63.8	64.1
.9	59.1	59.4	59.7	60.0	60.3	60.6	60.9	61.2	61.5	61.8	62.1	62.4	62.8	63.1	63.3	63.7

Pol.= Brix	41.6	41.8	42.0	42.2	42.4	42.6	42.8	43.0	43.2	43.4	43.6	43.8	44.0	44.2	44.4	44.6
15.0	68.1	68.4	68.7	69.0	69.4	69.7	70.0	70.3	70.7	71.0	71.3	71.7	72.0	72.3	72.6	73.0
.1	67.6	67.9	68.3	68.6	68.9	69.2	69.6	69.9	70.2	70.5	70.9	71.2	71.5	71.8	72.2	72.5
.2	67.1	67.4	67.7	68.1	68.4	68.7	69.1	69.4	69.7	70.0	70.3	70.7	71.0	71.3	71.6	71.9
.3	66.6	67.0	67.3	67.6	67.9	68.2	68.6	68.9	69.2	69.5	69.8	70.2	70.5	70.8	71.1	71.4
.4	66.2	66.5	66.8	67.2	67.5	67.8	68.1	68.4	68.7	69.0	69.4	69.7	70.0	70.3	70.7	71.0
.5	65.7	66.0	66.4	66.7	67.0	67.3	67.6	67.9	68.3	68.6	68.9	69.2	69.5	69.9	70.2	70.5
.6	65.3	65.6	65.9	66.2	66.5	66.8	67.2	67.5	67.8	68.1	68.4	68.7	69.0	69.3	69.7	70.0
.7	64.9	65.1	65.5	65.8	66.1	66.4	66.7	67.0	67.3	67.7	68.0	68.3	68.6	68.9	69.2	69.6
.8	64.4	64.7	65.0	65.3	65.6	65.9	66.3	66.6	66.9	67.2	67.5	67.8	68.1	68.4	68.7	69.0
.9	64.0	64.3	64.6	64.9	65.2	65.5	65.8	66.1	66.4	66.7	67.1	67.4	67.7	68.0	68.3	68.6

HORNE'S TABLE—(Continued).

Pol. =	44.8	45.0	45.2	45.4	45.6	45.8	46.0	46.2	46.4	46.6	46.8	47.0	47.2	47.4	47.6	47.8
Brix 15.0	73.3	73.6	73.9	74.3	74.6	74.9	75.3	75.6	75.9	76.2	76.6	76.9	77.2	77.5	77.9	78.2
.1	72.8	73.1	73.5	73.8	74.1	74.4	74.8	75.1	75.4	75.7	76.1	76.4	76.7	77.0	77.4	77.7
.2	72.3	72.6	72.9	73.2	73.6	73.9	74.2	74.5	74.8	75.2	75.5	75.8	76.1	76.5	76.8	77.1
.3	71.8	72.1	72.4	72.7	73.1	73.4	73.7	74.0	74.3	74.7	75.0	75.3	75.6	75.9	76.3	76.6
.4	71.3	71.6	71.9	72.2	72.5	72.9	73.2	73.5	73.8	74.1	74.5	74.8	75.1	75.4	75.7	76.0
.5	70.8	71.1	71.4	71.7	72.0	72.4	72.7	73.0	73.3	73.6	73.9	74.3	74.6	74.9	75.2	75.5
.6	70.3	70.6	70.9	71.2	71.5	71.9	72.2	72.5	72.8	73.1	73.4	73.7	74.1	74.4	74.7	75.0
.7	69.8	70.1	70.5	70.8	71.1	71.4	71.7	72.0	72.3	72.6	73.0	73.3	73.6	73.9	74.2	74.5
.8	69.4	69.7	70.0	70.3	70.6	70.9	71.2	71.6	71.8	72.1	72.4	72.8	73.1	73.4	73.7	74.0
.9	68.9	69.2	69.5	69.8	70.1	70.4	70.8	71.1	71.4	71.7	72.0	72.3	72.6	72.9	73.2	73.5

Pol. =	48.0	48.2	48.4	48.6	48.8	49.0	49.2	49.4	49.6	49.8	50.0	50.2	50.4	50.6	50.8	51.0
15.0	78.5	78.9	79.2	79.5	79.8	80.2	80.5	80.8	81.1	81.5	81.8	82.1	82.5	82.8	83.1	83.4
.1	78.0	78.3	78.7	79.0	79.3	79.6	79.9	80.3	80.5	80.9	81.3	81.6	81.9	82.2	82.6	82.9
.2	77.4	77.7	78.1	78.4	78.7	79.0	79.4	79.7	80.0	80.3	80.7	81.0	81.3	81.6	81.9	82.3
.3	76.9	77.2	77.5	77.9	78.2	78.5	78.8	79.1	79.4	79.8	80.1	80.4	80.8	81.1	81.4	81.7
.4	76.4	76.7	77.0	77.3	77.6	78.0	78.3	78.6	78.9	79.2	79.6	79.9	80.2	80.5	80.8	81.1
.5	75.8	76.2	76.5	76.8	77.1	77.4	77.7	78.1	78.4	78.7	79.0	79.3	79.6	79.9	80.3	80.6
.6	75.3	75.6	75.9	76.3	76.6	76.9	77.2	77.5	77.9	78.1	78.5	78.8	79.1	79.4	79.7	80.0
.7	74.8	75.1	75.5	75.8	76.1	76.4	76.7	77.0	77.3	77.6	78.0	78.3	78.6	78.9	79.2	79.5
.8	74.3	74.6	74.9	75.2	75.5	75.9	76.2	76.5	76.8	77.1	77.4	77.7	78.0	78.3	78.6	79.0
.9	73.8	74.1	74.4	74.7	75.1	75.4	75.7	76.0	76.3	76.6	76.9	77.2	77.5	77.8	78.1	78.4

Pol. =	51.2	51.4	51.6	51.8	52.0	52.2	52.4	52.6	52.8	53.0	53.2	53.4	53.6	53.8	54.0	54.2
15.0	83.8	84.1	84.4	84.7	85.1	85.4	85.7	86.1	86.4	86.7	87.0	87.4	87.7	88.0	88.3	88.7
.1	83.2	83.5	83.8	84.2	84.5	84.8	85.1	85.5	85.8	86.1	86.5	86.8	87.1	87.4	87.8	88.1
.2	82.6	82.9	83.2	83.6	83.9	84.2	84.5	84.9	85.2	85.5	85.8	86.1	86.5	86.8	87.1	87.4
.3	82.0	82.3	82.7	83.0	83.3	83.6	83.9	84.3	84.6	84.9	85.2	85.5	85.9	86.2	86.5	86.8
.4	81.5	81.8	82.1	82.4	82.7	83.1	83.4	83.7	84.0	84.3	84.6	85.0	85.3	85.6	85.9	86.2
.5	80.9	81.2	81.5	81.8	82.2	82.5	82.8	83.1	83.4	83.7	84.1	84.4	84.7	85.0	85.3	85.6
.6	80.3	80.6	81.0	81.3	81.6	81.9	82.2	82.5	82.8	83.2	83.5	83.8	84.1	84.4	84.7	85.0
.7	79.8	80.1	80.4	80.8	81.1	81.4	81.7	82.0	82.3	82.6	82.9	83.3	83.6	83.9	84.2	84.5
.8	79.3	79.6	79.9	80.2	80.5	80.8	81.1	81.4	81.7	82.0	82.4	82.7	83.0	83.3	83.6	83.9
.9	78.7	79.1	79.4	79.7	80.0	80.3	80.6	80.9	81.2	81.5	81.8	82.1	82.4	82.7	83.1	83.4

HORNE'S TABLE—(Continued).

Pol. =	54.4	54.6	54.8	55.0	55.2	55.4	55.6	55.8	56.0	56.2	56.4	56.6	56.8	57.0	57.2	57.4
Brix 15.0	89.0	89.3	89.7	90.0	90.3	90.6	91.0	91.3	91.6	91.9	92.3	92.6	92.9	93.3	93.6	93.9
.1	88.4	88.7	89.1	89.4	89.7	90.0	90.4	90.7	91.0	91.3	91.7	92.0	92.3	92.6	93.0	93.3
.2	87.9	88.1	88.4	88.8	89.1	89.4	89.7	90.1	90.4	90.7	91.0	91.3	91.6	91.9	92.3	92.6
.3	87.1	87.5	87.8	88.1	88.4	88.8	89.1	89.4	89.7	90.0	90.4	90.7	91.0	91.3	91.6	92.0
.4	86.5	86.9	87.2	87.5	87.8	88.1	88.5	88.8	89.1	89.4	89.7	90.1	90.4	90.7	91.0	91.3
.5	86.0	86.3	86.6	86.9	87.2	87.5	87.9	88.2	88.5	88.8	89.1	89.4	89.7	90.1	90.4	90.7
.6	85.4	85.7	86.0	86.3	86.6	86.9	87.2	87.6	87.9	88.2	88.5	88.8	89.1	89.9	89.7	90.1
.7	84.8	85.1	85.4	85.7	86.0	86.3	86.7	87.0	87.3	87.6	87.9	88.2	88.6	89.2	89.2	89.5
.8	84.2	84.5	84.8	85.1	85.4	85.8	86.1	86.4	86.7	87.0	87.3	87.6	87.9	88.2	88.5	88.9
.9	83.7	84.0	84.3	84.6	84.9	85.2	85.5	85.8	86.1	86.4	86.7	87.1	87.4	87.7	88.0	88.3

Pol. =	57.6	57.8	58.0	58.2	58.4	58.6	58.8	59.0	59.2	59.4	59.6	59.8	60.0	60.2	60.4	60.6
15.0	94.2	94.6	94.9	95.2	95.5	95.9	96.2	96.5	96.9	97.2	97.5	97.8	98.2	98.5	98.8	99.1
.1	93.6	93.9	94.3	94.6	94.9	95.2	95.6	95.9	96.2	96.5	96.9	97.2	97.5	97.8	98.2	98.5
.2	92.9	93.2	93.6	93.9	94.2	94.5	94.8	95.2	95.5	95.8	96.1	96.5	96.8	97.1	97.4	97.7
.3	92.3	92.6	92.9	93.3	93.6	93.9	94.2	94.5	94.9	95.2	95.5	95.8	96.1	96.4	96.8	97.1
.4	91.6	92.0	92.3	92.6	92.9	93.2	93.6	93.9	94.2	94.5	94.8	95.1	95.5	95.8	96.1	96.4
.5	91.0	91.3	91.6	92.0	92.3	92.6	92.9	93.2	93.5	93.8	94.2	94.4	94.8	95.1	95.4	95.7
.6	90.4	90.7	91.0	91.3	91.6	91.9	92.2	92.6	92.9	93.2	93.5	93.8	94.1	94.5	94.8	95.1
.7	89.8	90.1	90.4	90.7	91.0	91.4	91.7	91.9	92.3	92.6	92.9	93.2	93.5	93.9	94.2	94.5
.8	89.2	89.5	89.8	90.1	90.4	90.7	91.0	91.3	91.6	91.9	92.3	92.6	92.9	93.3	93.5	93.8
.9	88.6	88.9	89.2	89.5	89.8	90.1	90.4	90.7	91.0	91.4	91.7	92.0	92.3	92.6	92.9	93.2

Pol. =	60.8	61.0	61.2	61.4	61.6	61.8	62.0	62.2	62.4	62.6	62.8	63.0	63.2	63.4	63.6	63.8
15.0	99.5	99.8					100.0		100.0							
.1	98.8	99.1	99.5	99.8	99.4	99.7	100.0	99.6	99.3	98.6	99.9	99.5	99.9	99.5	99.8	99.5
.2	98.1	98.4	98.7	99.0	98.7	99.0	98.6	99.0	98.6	98.9	99.5	98.8	99.5	98.1	99.2	98.8
.3	97.4	97.7	98.0	98.4	98.0	98.3	98.0	98.3	98.0	98.6	98.5	98.5	97.8	98.1	98.5	98.1
.4	96.7	97.1	97.4	97.7	97.3	97.6	97.3	97.6	97.3	97.6	97.9	97.5	97.2	97.5	97.8	
.5	96.1	96.4	96.7	97.0	96.6	97.0	96.7	97.0	96.6	96.9	97.2	96.9				
.6	95.4	95.8	96.0	96.3	96.0	96.3	96.0	96.3	96.0	96.3	96.6					
.7	94.8	95.1	95.4	95.7	95.4	95.7	95.4	95.7								
.8	94.1	94.4	94.7	95.0		95.0										
.9	93.5	93.8	94.1													

366. INDEX OF SUBSTANCES THAT ARE OR HAVE BEEN USED FOR PURIFYING, DECOLORIZING AND CLARIFYING SUGAR-CONTAINING SOLUTIONS.[1]

(A list of the abbreviations of references is given at the end of this index.)

I. SULPHUR; ITS ACIDS, COMPOUNDS AND DERIVATIVES.

1. Sulphur (Leuchs III, 86; 1836).
2. Hydrogen Sulphide (Sievier, 1847, in Woodcroft, 94; Hlavati, Chs., 28, 1180).
3. Hydrogen Persulphide (Hlavati, Chs., 28, 1180).
4. Sulphuric Acid (Achard, about 1800, Gesch., 407; Kessler, Z., 16, 760; Hagemann, D. Z., 12, 491).
5. Sulphuric Acid with Lime (Mége, D., 115, 215).
6. Sulphuric Acid with Zinc Chloride (Thiele, Chs., 20, 404).
7. Sulphuric Acid with Zinc Sulphate (Terry, 1833, in Woodcroft, 54).
8. Potassium or Sodium Sulphate (Macfadyen, 1830, Gesch., 423).
9. Ammonium Sulphate (Dullo, D., 155, 71; Beanes, D., 167, 220).
10. Sulphuric with Sulphurous Acid (Possoz, D., 170, 64).

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11. Sulphurous Acid (Drapiez, "Bull. de la Société d'encourag.," Paris, 1811, X. 56; Perpere, 1812, and Dubrunfaut, 1829, Zerban, 1908.
12. Sulphurous Acid and Hydrogen Sulphide (Hlavati, Bl. Ass., 16, 759).
13. Sulphurous Acid with Calcium Bisulphite (Stolle, D., 114, 305).
14. Sulphurous Acid with Chloride of Lime and Phenol (Menier, Bl. Ass., 10, 165.)
15. Sulphurous Acid and Phenol (Kowalski, Z., 55, 396).
16. Sodium Sulphite (Perrier and Possoz, Z., 12, 128; Rümpler, N. Z., 30, 204).
17. Potassium Sulphite (Cassel and Kempe, S. ind., 47, 684).
18. Ammonium Sulphite (Beanes, D., 167, 220).
19. Calcium Sulphite (Prout, 1810; Melsens, C. r., 55, 729; Calvert, Z., 12, 500).
20. Barium Sulphite with Oxygen (Bouillant, S. ind., 50, 189).
21. Magnesium Sulphite (Mehay, Z., 23, 47; Drost and Schulz, Oe., 1885, 891; Degener, D. Z., 24, 203).
22. Lead Sulphite (Scoffern, 1847, in Woodcroft, 98).
23. Ferrous Sulphite (Englert and Becker, N. Z., 16, 70).
24. Aluminum Sulphite (Boulin, 1846, in Zerban, 15; Brandé, 1846, Z., 44, 455; Mehay, Z., 23, 27).
25. Aluminum Sulphite with Calcium Hydrate (Schubarth, Z., 2, 129).

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[1] Compilation by Prof. Dr. Edmund O. von Lippmann, printed in Deutsche Zuckerindustrie, Vol. XXXIV, p. 9 (Jan., 1909).—Translation supplied through the courtesy of Dr. Charles A. Browne, New York Sugar Trade Laboratory.

VI. METALS AND THEIR COMPOUNDS.

254. Aluminum Dust (Ranson, Chz., 21, 1033).

255. Aluminum Dust with Alkalies (Ranson, see above).

256. Aluminum Dust with Ammonium Sulphite (Besson, Bl. Ass., 19, 800).

257. Aluminum Dust with Hydrofluoric Acid or Hydrofluosilicic Acid (Mertens, Z., 54, 118).

258. Aluminum Alloys, also with Copper or Zinc Dust (Bessen, Chz., 28, 529).

259. Aluminum Chloride (Nash, 1852, in Woodcroft, 151; Heffter, Oe., 22, 71).

260. Aluminum Chloride with Lime (Siemens, St. J., 18, 256).

261. Aluminum Fluoride (Kessler, Z., 15, 525).

262. Alumina (about 700 in Egypt, Gesch., 135 and 295; Murray, about 1802, Gesch., 368).

263. Hydrate of Alumina (Howard, 1810, Gesch., 368; Z., 2, 92).

264. Colloidal Alumina (Löwig, Z., 29, 905).

265. Fuller's Earth (Fritsche, Z., 35, 361).

266. Sodium Aluminate also with Sulphurous Acid (Besson, Bl. Ass., 25, 733).

267. Aluminate of the Alkaline Earths (Plicque, D. Z., 2, 51).

268. Calcium Aluminate (Oxland, Z., 2, 92).

269. Basic Calcium Aluminate (Gui, Z., 46, 202).

270. Tetra- and Hexa-Basic Aluminate of Calcium or Barium (Gin and Leleux, Bl. Ass., 16, 707).

271. Aluminate of Barium or Strontium (Jacquemart, French Patent, 51, 908, 1861; Rembert, Bl. Ass., 20, 747).

272. Barium Aluminate with Ammonia Alum (Geistodt, Z., 28, 843).

273. Barium Aluminate with Sulphurous Acid (Jaluzot, S. ind., 63, 690).

274. Barium Aluminate with Aluminum Sulphate (Jaluzot, see above).

275. Magnesium Aluminate (used about 1888; Hlavati, S. ind., 65, 674).

276. Sulphite of Alumina (Kessler, Z., 15, 525; Massé, 1860, Z., 44, 458).

277. Sulphate of Alumina with Phosphoric Acid (Stein and Crosfield, Oe., 28, 183).

278. Basic Sulphate of Alumina (Hunt, Z., 30, 361; Brünjes, D. Z., 25, 19).

279. Alum (about 700 in Egypt, Gesch., 135; Hermbstaedt, "Anleit. z. Fabrik. des Zuckers," Berlin, 1811, 86).

280. Alum with Sodium Carbonate (Salisbury, Z., 54, 1274).

281. Alum with Lime and Alcohol (Derosne, Oe., 23, 948).

282. Alum also with Sulphate of Alumina (Howard, 1812, Z., 44, 446).

283. Aluminum Acetate (Oxland, 1850, in Ling-Roth., 121; Schubarth, Z., 2, 92).

284. Tartrate of Alumina (Dumas, C. Z., 1906, 939).

285. Oxalate of Alumina (Sievier, 1847, in Woodcroft, 94; Mialhe, D., 99, 482; Dumas, C. Z., 1906, 939).

286. Alminum Phosphate (Oxland, Z., 2, 92, and 2, 130).

287. Aluminum Silicate (Maumené, Lehrbuch).

VIII. ELECTROLYTIC SUBSTANCES.

ABBREVIATIONS OF REFERENCES.

Abbreviations.	Reference.
Barta	Claassen-Barts's "Zuckerfabrikation" (Leipzig, 1905).
B	Berichte der deutschen chemischem Gesellschaft (R = Referate).
Bl.	Bulletin de la Société chimique.
Blanchette Zoega	"Manuel du fabricant et du raffineur de sucre" (Paris, 1833).
Bley	Bley's "Zuckerbereitung aus Runkelrüben" (Halle, 1836).
Bl. Ass.	Bulletin de l'association des chimistes.
Chs.	Chemiker-Zeitung (R = Repertorium).
C. r.	Comptes rendus
C. Z.	Centralblatt für die Zuckerindustrie.
D.	Dingler's polytechnisches Journal.
D. Z.	Die Deutsche Zuckerindustrie.
Gesch.	Lippmann's "Geschichte des Zuckers" (Leipzig, 1890).
J. fabr.	Journal des fabricants de sucre.
Ling-Roth	Ling-Roth's "Guide to the Literature of Sugar" (London, 1890).
Leuchs	Leuchs "10,000 Erfindungen und Ansichten" (Nürnberg, 1871).
Maumené	Maumené's "Traité de la fabrication du sucre" (Paris, 1878).
N. Z.	Neue Zeitschrift für Rübensuckerindustrie.
Oe.	Oesterreichisch-Ungarische Zeitschrift für Zuckerindustrie.
Prager Marktb.	Prager Marktbericht.
S. C.	The Sugar Cane.
S. ind.	La sucrerie indigène et coloniale.
St. J.	Stammer's "Jahresbericht der Zuckerfabrikation."
Weber	Weber's "Zeitblatt für Gewerbetreibende."
Woodcroft	Woodcroft's "Abridgments of Specifications relating to Sugar" (London, 1871).
Z.	Zeitschrift des Vereins der Deutschen Zuckerindustrie.
Z. ang.	Zeitschrift für angewandte Chemie.
Z. B.	Zeitschrift für Zuckerindustrie in Böhmen.
Zerban	Zerban's "Louisiana Bulletin No. 103 (Baton Rouge, 1908).

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